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ENVIRONMENTAL ENGINEERING AND SUSTAINABILITY

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CHAPTER 1

THERMODYNAMICS AND ITS SCOPE

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Thermodynamics examines how heat, work, and temperature relate to energy, radiation, and the physical characteristics of matter. It specifically discusses how heat conduction is changed into or out of other types of energy, and how this process affects matter. The energy that heat produces is known as thermal energy. The movement of small particles inside an item causes heat to be produced, and the quicker these particle move, the more produced heat

Mechanics and Thermodynamics concept

It is important to note the difference between mechanics and thermodynamics. In mechanics, we only focus on how particles or bodies move when forces and torques are applied. The motion of something like the system as a whole, however, is unimportant to thermodynamics. It solely cares about the body's macroscopic interior condition

Different branches of thermodynamics

Four disciplines of thermodynamics are distinguished:

1. Classical Thermodynamics
2. Statistical Thermodynamics
3. Chemical Thermodynamics
4. Equilibrium Thermodynamics

Classical Thermodynamics

In classical thermodynamics, a macroscopic perspective is used to analyses the behavior of matter. In order to compute other qualities and forecast the features of the substance conducting the process, people take into account units like temperature and pressure.

Statistical Thermodynamics

Every molecule is examined in statistical thermodynamics, meaning that the characteristics of each molecule and their interactions are taken into account to describe the activities of a group of molecules.

Chemical Thermodynamics

The study of the relationship between work and heat in chemical reactions and state transitions is known as chemical thermodynamics.

Equilibrium Thermodynamics

The study of changes in matter and energy as they become closer to equilibrium is called equilibrium thermodynamics.

Thermodynamic Systems

The area of matter having a distinct border that receives our attention is called a thermodynamic system. The system border may be fixed or flexible, real or imagined.

Three different system kinds exist

Isolated system

A system that is isolated from its surroundings is unable to exchange mass and energy. The entire cosmos is seen as a standalone system.

Closed System:

When two closed systems are separated by a barrier, mass cannot be transferred but energy may. Examples of conduction and convection are a refrigerator and the decompression of gas in a piston-cylinder arrangement.

Open system

Mass and energy may both be moved between a system and its surroundings in an open system. An illustration of an open platform is a steam turbine.

Thermodynamic Process

When a system experiences an energetic shift that is linked to variations in pressure, volume, and internal energy, a thermodynamic process is initiated.

There are four distinct types of thermodynamic processes, and they are as follows:

Adiabatic process

There is no heat transport from or to the system during an adiabatic process

Isochoric process

An isochoric process is one in which there is no volume change and no system activity.

Isobaric process

An isobaric process is one in which there is no change in pressure.

Isothermal process.

A process when there is no temperature change is known as an isothermal process.

A thermodynamic cycle is a process, or a series of events, carried out in such a way that the system's beginning and end states are identical. Cycled action or cyclic processes are other names for thermodynamic cycles.

Land degradation

It is difficult to trace the origins of the phrase "land degradation," which is now commonly used and has a variety of encompassing definitions. The United Nations Convention to Prevent Desertification (UNCCD), which went into force in December 1996, defines "Land" as a "terrestrial bio-productive system that includes soil, plants, other biota, and water." and the ecological and hydrological processes that operate within the system", and its "degradation" as "reduction or loss of biological productivity, resulting from land uses, or combination ofprocesses, such as soil erosion deterioration of soil properties and long-term loss of natural vegetation". Using the more recent Millennium Ecosystem Assessment conceptual framework (Millennium Ecosystem Assessment 2005a), the above rather lengthy definition of "land" can be shortened to "A terrestrial ecosystem," and "land degradation" - to "reduction or loss of ecosystem services, notably the primary production service". Figure 1.1 depicts components of terrestrial ecosystems relevant to "land degradation" - soil, and its vegetation cover (be it grass, shrubs, or trees), as well as "land degradation"-relevant services of such ecosystems; their linkages (e.g., the food provisioning service supported by the primary production service) and inter-linkages (e.g., between soil and vegetation cover) impinge on the people whose livelihood and thus well-being are directly dependent.

Consequently, the term "land degradation" is only relevant in the social context of human value received through ecosystem usage by people (Blaikie and Brookfield 1987). It may therefore be measured by the impact of this usage on the service of primary production, which provides biological goods on which much of human well-being is dependent. As a result, the degree of "ecosystem health" or its opposing process of "land degradation" is frequently determined directly by analysing the soil, plant cover, or primary productivity. This is due to the fact that each of these is a correlate of the other.

Land degradation can also be deduced indirectly by evaluating crop output (for example, the food provisioning service) or even by utilising indices of human well-being. Formerly, land degradation evaluations focused on soil characteristics, however vegetation assessments and, in particular, primary production assessments have lately become increasingly popular. Nevertheless, because the functional relationships between soil and plant characteristics are not always linear (Prince 2002), the values for "land degradation" at a given location may vary depending on the variable used to describe it.

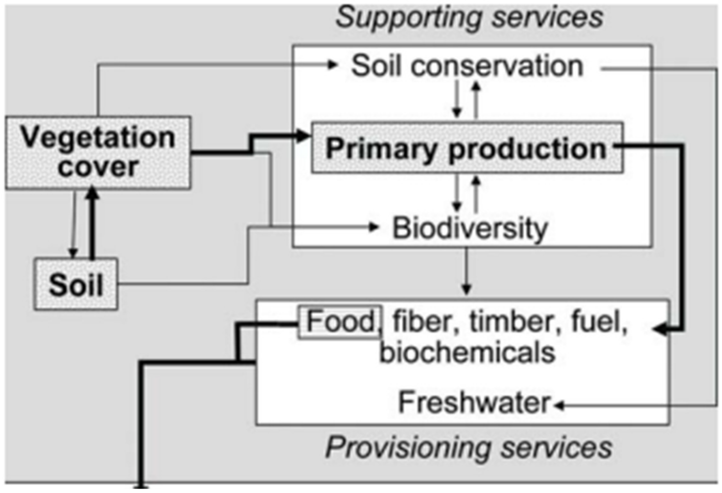

Figure 1.1 represent the Linkages within and between supporting and provisioning services

The requirement for worldwide assessment

Land degradation, manifested as soil salinization and water-logging (due to overcultivation and poor river course management), and soil loss (due to overgrazing and deforestation), has been blamed for the demise of ancient civilizations in both the old and new worlds, as well as 20th century human suffering in both industrial (e.g., the 1930s "dust bowl") and developing (e.g., the 1970s and 1980s Sahel droughts) countries Although vivid qualitative reports of such catastrophes are widespread, their scope in terms of damaged areas and afflicted communities has seldom been adequately assessed.

The realisation of the environment-development interlinkages that emerged throughout the second half of the twentieth century provided the impetus for quantitative evaluation of land degradation on a global rather than a local or regional scale. This realisation, that intensified development reduces the environment's ability to support it, was heightened by the emerging recognition that many environmental and associated social problems are of a trans-boundary nature, and thus addressing them requires regional, and often global, attention, rather than just local (e.g. Agenda 21. These realizations appear to have aided procedures leading to the negotiation and adoption of legally binding worldwide, international accords. The three "Rio Conventions," which address land degradation either directly (UNCCD) or indirectly (Convention on Biodiversity (CBD) and the United Nations Framework Convention on Climate Change, are particularly noteworthy in this perspective. The pragmatic emphasis of these three agreements is the tacit and frequently explicit contrast they draw between industrial and developing nations in terms of commitments. The industrialized nations are expected, among other things, to aid the developing nations in tackling their environmental issues, such as land degradation; at least implicitly, "their" environmental problems are "ours" as well, due to their global character. The reaction of three important parties to this distinction was favourable for commencing global evaluations of land degradation and its societal ramifications, rather than merely local assessments. Developing country signatories to UN agreements were driven not only to describe and quantify the geographical and demographic extent of difficulties inside their borders, but also to impress developed nation signatories on the global nature of their concerns. When challenged with this argument, developed nation parties needed techniques for consistently qualifying land deterioration. The United Nations system's specialised agencies and programmes, UN-associated entities, and other international organisations participating in the coordination and delivery of international development aid constitute a third stakeholder group. In their efforts to broaden and revitalise their operations, these organisations have also been influential in advancing the concept of land degradation as a global syndrome, lobbying for its inclusion in their mandates. As a result, by the 1980s, the groundwork was laid for the launch of worldwide initiatives to analyse land degradation. It was implicitly assumed that a global assessment, which would of course be based on local assessments from around the world, would accomplish more than the sum of local assessments: even if these assessments did not generate additional insight into the causes and responses to local land degradation, the added benefit would be in impressing decision- and policy-makers at all levels, from local grassroots to international, with the need to address lan degradation.

A worldwide assessment of land degradation

Only five attempts have been made in the last 30 years to carry out and present assessments of land degradation on a global scale, either by an individual researcher (H. E. Dregne) or by international organisations. As a first attempt, the production of a "Generalized map of the status of desertification on arid lands" included in one of UNCOD's official documents, which "was based on very little data or experience and has only historical significance", the coverage and quality of these assessments improved.

Yet, none of them can be regarded as a credible source of knowledge or a valuable resource for policymaking. The reasons for the deficiencies of the five evaluations vary, but they all have two key causes: (a) intrinsic challenges in identifying and hence evaluating the attribute selected to represent "land degradation," and (b) varied degrees of field data scarcity. The dispersion of estimates for the total geographical extent of global land degradation, as described in this chapter, best expresses these inadequacies. Despite past and ongoing current attempts, no satisfactory evaluation of land degradation at the global scale is now available, and is not projected to be accessible until the end of the first decade of the twenty-first century. Nonetheless, preliminary findings from ongoing research suggest that figures attributed to the magnitude of the land degradation problem, used in the political arena, and cited in grey literature may have been exaggerated. Given this, and motivated by the Intergovernmental Panel on Climate Change (IPCC) assessment reports that provide future projections, concerned decision-makers and scientists argue that assessing trends in land degradation is more practical and useful for mobilising action than simply assessing the current state of global degradation. As will be discussed more in the following sections, worldwide assessments of land degradation trends are rare at the moment, while potential approaches for doing so are being developed.

Worldwide land degradation and aridification

The five "global" evaluations differ substantially in terms of their products, as well as their data coverage and quality. GLASOD has the most attention and has participated in the most extensive effort to date, but it also receives a lot of criticism. GLASOD, on the other hand, was preceded by

Harold Dregne assessment products, which, unlike GLASOD, which addressed global "land degradation", addressed "desertification" in "arid lands," i.e. in drylands only, as the product name indicates.

Because desertification is defined by the UNCCD as “land degradation in arid, semi-arid, and dry sub-humid areas" (UNEP May 1995), and because these three climatic zones (along with the hyper-arid zone) are "drylands" - lands where water input via precipitation relative to output in all forms, aggregated to "potential evapotranspiration" (i.e., the "aridity index") ranges between 0.05 In addition, for the production of the Global Atlas.

The relevant literature does not explain why an aridity index value of 0.65 was chosen to distinguish drylands from non-drylands. The dry-subhumid zone defined by that number has highly seasonal rainfall with less than 25% inter-annual rainfall variability. UNESCO (1977) classified this zone as dryland because it is "particularly prone to deterioration, possibly exacerbated by seasonality of rainfall, drought spells, and increasing intensity of human use" (Middleton and Thomas 1997). After the aridity extent of the drylands has been determined in this manner, one can only investigate how the drylands differ from non-drylands in aspects related to land degradation.

The Millennium Ecosystem Assessment revealed that, when compared to all other terrestrial major ecosystem types, the drylands, as defined by UNESCO (1977) and the WAD (Middleton and Thomas 1997), have the lowest net primary productivity and the highest population growth rate (during the last two decades of the twentieth century). This combination may explain for increased human strain on restricted natural production, making drylands more vulnerable to land degradation than non-drylands. Indeed, using GLASOD data, land degradation in the "susceptible drylands" (hyperarid drylands are not susceptible to desertification, so all other three dryland zones are termed "susceptible" [to desertification]) is significantly higher (20% of their global areas) than in the "other" areas - primarily the "humid" areas (39.2% of global land), but also the hyperarid ones (7.5% of global land, Middleton and Thomas 1997).

The inclusion of the most and least arid worldwide areas in the category of "non-drylands" is a flaw of the GLASOD data analysis. Even if land degradation is more widespread in drylands than in non-drylands, the fact that all published estimates of present land degradation focus on "desertification," i.e., deterioration in drylands solely, can be attributed to political rather than biophysical factors. Were spurred by the public and political consequences of the Sahelian droughts of the 1970s and 1980s. These political procedures, which culminated in the formation of a legally enforceable document addressing "desertification," necessitated an evaluation of soil erosion where it may occur, namely in the "vulnerable" drylands, rather than globally.

The objective "to combat desertificationin countries experiencing desertification, particularly in Africa through effective action supported by international cooperation and partnership arrangements", as implied by Article 2 ("Objectives") of the UNCCD, means an effective orchestration of industrial countries' support for dryland developing countries in effectively addressing their land degradation problems. Indeed, when the Convention was opened for signature in October 1994, developing "affected" countries (countries with lands "affected or threatened by desertification" - UNCCD) rushed to ratify it, but a few "non-affected" developing countries, i.e. countries that do not have drylands and thus cannot be "affected," also joined. The number of Parties has steadily increased since the Convention was opened for signatures, but by 1997, some 3-4 years after the Convention was opened for signatures and about one year after the Convention entered into force, the rate of increase in the number of joining "affected" countries had slowed. At the same time, the number of non-affected developing countries joining the Convention was still on the rise (Fig. 1.3), decreasing slightly in mid-1999, but more countries in this group joined at a higher rate than affected countries until 2004. This interest in the UNCCD by developing non-dryland countries culminated in the addition of a new, fifth implementation annex to the UNCCD, one for Central and Eastern European Countries, which includes 17 developing countries, 11 of which have no drylands within their borders and thus no desertification to combat. Presently, 191 countries.

The UNCCD has 93 developing dryland ("affected") nations and 69 non-dryland developing countries as parties; the ratio of non-dryland to dryland developing countries increased from 0.33 in 1995 to 0.74 in 2004. It should also be emphasised that a considerable majority of emerging dryland nations, particularly those who joined the UNCCD late, have only the least dry drylands, namely dry-subhumid zones, inside their borders, or have very little drylands at all. The majority of non-dryland developing nations, as well as those with a very minor share of drylands on their territory, that have joined the UNCCD are impacted by or vulnerable to land degradation. Their motivation for joining the UNCCD is to reap the benefits of donor countries and international funding agencies such as the Global Environment Facility (GEF) supporting projects that address the problem of "land degradation" anywhere in the developing world, rather than focusing on "desertification," which occurs only in drylands. Nevertheless, there are several notable situations when land degradation in a non-dryland nation is significantly worse than in any dryland country (e.g. Iceland, Arnalds et al. 2001). Consequently, for all practical purposes the UNCCD has grown into a tool for tackling global land degradation, not necessarily restricted to drylands and to "desertification". This is the justification for assigning globality to assessments of desertification at the global scale, providing the assessment covers land degradation only in the drylands (i.e., desertification) or also in non-drylands.

Degradation degree and degradation severity

Degradation assessment, particularly on a global scale, consists of three stages: (a) creating numerical data based on ground observations and measurements; (b) translating the numerical data to map units; and (c) collecting statistics by submitting map units to various analyses. Concerning the first stage, the two major assessments (for more information,) were based on observations of several land (mostly soil) attributes, which were more often qualified than quantified, and then aggregated into a few classification units ranging from "low" to "high" degradation "degrees."

In the second stage, the translation of these identified deterioration degrees into map units frequently encounters a mismatch between the ground sample scale and the size of the map unit. As a result, only one component of each mapping unit may be degraded, and it is unknown which part of the unit is degraded and which is not. As a result, when generating cartographic output, the sole alternative is to shade the whole polygon, which creates an exaggerated picture of the level of deterioration. As a result, two separate statistics may apply in the third stage of calculating land degradation data. The first considers simply the actual deteriorated area, aggregating land units based on their degree of deterioration. The second approach is to utilise a composite estimate of "deterioration severity," which is a mix of degradation degree and geographical extent within mapping units It is said that, whilst the later leads in an exaggerated figure of deterioration, the former does not.

This might be an underestimation of the whole phenomenon. This is due to the fact that it does not consider (a) the influence of the degraded site on the usage of the land surrounding it, (b) off-site consequences such as sedimentation and others, and (c) the negative effects on the economy as a whole, whether at the village, regional, or national levels.

For these reasons, FAO, for example, used "deterioration severity" as an indication of the overall level of degradation within a mapping unit, nation, or region when displaying the GLASOD database applied to specific countries on its website (FAO no date b). Although, "the global maps (in WAD) are meant to offer an overall, if exaggerated, sense of the degree of soil deterioration" (Middleton and Thomas 1997), "only a portion of each mapping unit is really impacted by degradation". GLASOD is the only worldwide evaluation of current land degradation rather than simply the dryland scale. Its results give a range of estimates for the worldwide geographic extent of land degradation, ranging from 15% to 65% of total global land degradation.

The lowest number indicates ground data from the four "degree" degradation values, while the highest value represents the seemingly exaggerated degradation "severity" as seen on maps. The degree to which the soil is deteriorated and the proportional size of the degraded land within the drawn map units, within each of which only a portion of the delineated unit is degraded, characterise the severity of the degradation. These high percentages vary from 61% to 65%, depending on the worldwide land area estimations used to calculate the percent degraded. The highest degree of deterioration belongs to the intermediate groups, while the spatial extent of places with the highest degree of degradation is the lowest - just 6% of world land. To emphasise, these figures cover both drylands and non-drylands; for example, using the GLASOD database, the total degradation severity of Niger, a Sahelian dryland nation, is 27.7%, whereas Iceland, a humid, non-dryland country, is 35.7% (FAO no date b).

The amount of dryland deterioration in space

Summarises the important information on dryland degradation reported by the three major evaluations. There are significant differences in the "bottom line" which is frequently cited in public media and grey literature, depending on within- and between-assessment differences in methodology (using degree- or severity-degradation, trying to distinguish between erosion processes or between land uses, excluding or including "slight" degradation) and spatial coverage. Estimates range from 4% to 74% of drylands being desertified. When hyperarid regions are omitted, GLASOD calculates the greatest estimate of "severity" deterioration. The MA desk study's lowest estimate, which excludes the hyperarid, arises from attributing "desertification" status exclusively to the "very seriously deteriorated" stage. Consequently, assessing the worldwide geographical extent of the highest (fourth) deterioration categorization is required for meaningful comparison of the MA desk study with the two previous evaluations. Whether the hyperarid zone is removed or included, this varies from 0.1% to 0.6% of GLASOD to 4% and 10% of the MA desk research, respectively. It should be emphasised that the MA desk research used data quality control that was said to be stricter than GLASOD's. This may lend credence to the MA desk research numbers. Nevertheless, the tougher data control limited the whole worldwide dryland area covered by the MA desk research to only 62%, which may cast doubt on its credibility as a global evaluation.

The GLASOD ("Global Assessment of Land Degradation") project's title expressly tackles land degradation assessment, literally meaning an evaluation of the spatial breadth and severity of tangible land deterioration. Nonetheless, the World Atlas of Desertification (Middleton and Thomas 1997), the most widely publicised secondary source of GLASOD focusing on desertification, presents a map entitled "Soil degradation severity in susceptible drylands". The WAD text actually follows the original World Map of Desertification published for UNCOD by FAO, UNESCO, and WMO, in which many places classified as desertified qualified as such owing to local factors that indicated simply a possibility or hazard of being desertified.

Indeed, the UNCCD defines "affected areas" (i.e., regions impacted or threatened by desertification) as "arid, semi-arid, and/or dry sub-humid areas affected or threatened by desertification" (UNEP May 1995, Article 1h). Because all three dryland areas have the potential to become desertified, the UNCCD Secretariat created a booklet to commemorate the Convention's 10-year anniversary, which includes a map of the global drylands and the caption "Desertification in the Globe". Lastly, the Global Environment Facility (GEF) defines "degradation" (rather than merely "desertification") as "any kind of deterioration of the natural potential of land". As a result of the poor robustness of the concepts of "degradation" and "desertification," it appears that the literature on degradation assessment is frequently not easily accessible to explaining the present condition or the currently prevalent patterns of land degradation. On the other hand, most decision-makers and policymakers are concerned with the trend rather than the current status. As a result, vulnerability, which may give an early warning of an impending trend, need a strong therapy.

Vulnerability to deterioration and danger of decline

The Natural Resource Conservation Service (NRCS) of the United States Department of Agriculture conducted the "Global Desertification Vulnerability and Risk," a global evaluation of desertification susceptibility (USDA). It was initially published in conference proceedings (Eswaran and Reich 1998), and was later followed by a number of products: NRCS webpages.

The vulnerability of each land unit within the drylands is evaluated in this evaluation based on its soil qualities and their reaction to climatic conditions to which this land unit is usually exposed. The worldwide drylands' soil-climate links were divided into four sensitivity levels (Table 1.9). Based on the soil-climate relationship, these vulnerability levels are converted into four risk categories. The system of each land unit that is subject to human effect, as represented by the population density that utilises or relies on this land unit Human density ranges categorised into three classes, each interacting differently with each of the four vulnerability classes, set the guidelines for this transfer from vulnerability to risk classes. Hence, a high population density in a highly vulnerable region, for example, poses a very high danger of land degradation, whereas a low population density in a low vulnerability area poses a very low risk.

Except for hyperarid regions, the NRCS Degradation Vulnerability and Risk study covers the worldwide drylands, indicating that 84% of this domain is vulnerable to and at risk of desertification. This statistic is greater than the maximum value of GLASOD, which is 74% as GLASOD is designed to offer values of actual degradation, but the NRCS evaluation includes regions that are not desertified but are at high risk of being desertified.

fied. The fact that the discrepancy between the two evaluations is not much larger is also to be expected, as GLASOD may not have always specifically distinguished tangible desertification from susceptibility to and danger of desertification. Although the overall global vulnerability and risk for the drylands are the same, the difference between vulnerability and risk is seen when looking at the specific classes. It is clear that the majority of the 84% of vulnerable and at-risk drylands are in the low and moderate vulnerability classes (54% of total drylands), while the majority of these 84% are in the high and very high risk classes (53% of total drylands). Consequently, whereas 15% of the drylands are extremely vulnerable to desertification, 23% are extremely vulnerable to the vulnerability materialising when human pressure is included The distinction between vulnerability and risk values is that vulnerability is an intrinsic property that is time stable, but risk, based on population impact, can fluctuate with temporal changes in population size.

The authors of this assessment place a premium on "very high" classes of vulnerability and risk, referring to them as "desertification tension zones" - areas "where the potential decline in land quality is so severe as to trigger a whole range of negative socioeconomic conditions that could threaten political stability, sustainability, and general quality of life" (Eswaran and Reich 2001b). As a result, 23% of the drylands (excluding the hyperarid) are at extremely high danger of desertification (if not already desertified). Though the "Desertification of Arid Lands" (Dregne and Chou 1992) and MA desk study analyses addressed vegetation status as an attribute or expression of land degradation, soil degradation is emphasised in all global degradation assessments, and is the only feature assessed by GLASOD and the NCRS vulnerability and risk assessments Likewise, soil is inextricably related to plant cover and the ecological function of primary production, both of which are critical to human well-being (Fig. 1.1). Consequently, soil deterioration would not have been an issue if it had not resulted in decreased production, which is the final manifestation of desertification. The weight given to soil degradation rather than vegetation and productivity degradation by land degradation assessments may attest to the importance attributed to soil by the assessors, or it may indicate that soil properties are more amenable to quantification than vegetation and productivity attributes. Regarding the first alternative, it is worth noting that a social survey conducted in Zimbabwe discovered that dryland farmers saw soil erosion as a minor issue when compared to other farming-related difficulties (Grohs 1994). For the second alternative, developments in remote-sensing technology since these global land degradation assessments were created have made vegetation evaluation, particularly at the global scale, an appealing option for tackling land degradation.

Indeed, the WAD (Middleton and Thomas 1997) sought to integrate vegetation remote sensing with GLASOD data. The Normalized Difference Vegetation Index (NDVI) is a qualitative measure of vegetation phenology generated from remotely detected reflectance in specified spectral bands from living plants. The WAD team generated the Global Vegetation Index (GVI), which is the greatest daily NDVI value occurring during a week (derived from data of 16 km X 16 km spatial resolution pictures collected by the Advanced Very High Resolution Radiometer [AVHRR] satellite) averaged over a specific period (1983-1990 for the WAD study).

CHAPTER 2

VEGETATIVE BIOMASS

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This index measures plants' ability to photosynthesize and is predictive of vegetative biomass under a variety of environmental situations (Middleton and Thomas 1997). The WAD created a map showing worldwide coverage of GVI values, representing biomass variations as a five-grade scale from low to high, and superimposed it on the GLASOD four-degree scaled degradation severity map. As a result, the WAD team generated a map with a 20-color grid, with each hue representing an assumed connection between the severity of land degradation and the quality of the above-ground vegetation. This map, on the other hand, does not expressly address land degradation, but it may distinguish between observable deterioration and degradation risk. Areas with only moderate degradation severity but high GVI, for example, signal a degradation risk due to limited plant cover, even though the soil does not appear to have responded to this loss. Areas with high degradation severity and low GVI, on the other hand, are more likely to be already deteriorated. Lastly, locations with high degradation severity but low GVI may suggest encroachment of vegetation into an effected area. This WAD exercise is beneficial for attracting attention to the possibility of satellite images for deterioration evaluation, but it is not appropriate for performing statistical analysis of the database used to produce this product, as the WAD correctly concluded.

The MA desk study, the only global assessment that included vegetation detection via satellite imagery data in the information contributing to the overall assessment of dryland degradation, noted the limitations of such an approach due to difficulties in determining whether spatial variability in NDVI values is due to spatial changes in human impact or to temporal, inter-annual climate variability. The WAD team overcame this weakness by averaging the GVI values over a lengthy period of time. Yet, even this method was unable to discriminate between two similarly low long-term averaged vegetation signals, one created by a non-degraded condition of inherently low productivity land and the other by land of inherently high productivity but exposed to long-term human effect. Nevertheless, because vegetation and productivity in drylands immediately respond to fluctuations in rainfall, the difference between two sites that produced an identical signal may be identified if their rainfall regimes differ - the site with more rainfall is likely to be the damaged one. Conversely, two locations hit by the same rainfall will behave differently if the degree of human-induced influence, i.e., degradation, differs. Monitoring and comparing two separate regions' reactions in net primary production (NPP) as detected by satellite images and expressed by NDVI aggregated across the growing season (sumNDVI) to an equal 16-year inter-annual variation in rainfall provides a test for this assumption.

The increase in productivity caused by increased rainfall, is usually less in degraded areas than in non-degraded areas. The difference in reaction to rainfall increase between the two places can be linked to the two areas' inferior rainfall use efficiency Additionally, the data shown in may be used to calculate the ratio of NDVI (standing for NPP) to yearly precipitation, indicating the effectiveness of using rainwater for primary productivity and so referred to as "Rainfall Usage Efficiency" (RUE). In fact, the RUE of degraded regions is always lower than the RUE of non-degraded areas. However, RUE values vary between seasons (for example, similarly low rainfall in 92-93 and 02-03 growing seasons produced very different RUE responses, with the latter being much higher than the former), indicating that factors other than rainfall influence the efficiency of using moisture levels for primary productivity. Degradation is defined as a prolonged decrease in land production.

The evident relationships between ground-verified deterioration and its manifestation in remotely sensed productive indicators make one question why the various assessments yield such a broad range of estimates for the worldwide extent of land degradation. One theory is that this is due, at least in part, to the rather ambiguous definition of "land degradation," particularly "desertification," which does not provide a clear choice of variables to be measured (e.g., soil erosion or vegetation cover, etc.) and is ambiguous regarding the criteria for classifying observations into "degraded" or "non-degraded" classes. The data set given simply indicates that land degradation is best defined and quantified as a consistent decrease in land productivity (Prince 2002; Millennium Ecosystem Assessment 2005b).

The first is the emphasis on primary productivity. This variable is commonly assessed on the ground since it is the most economically relevant aspect of the land, and it incorporates all other biophysical variables that drive and interact with it. Its local ground evaluation can also be upscaled by using sensors on aerial or spaceborne devices that detect radiation bands reflected from plants. The second component is that simply identifying a decrease in productivity is inadequate and might be deceptive; it must be sustained in order to qualify as deterioration. The key problem in identifying deterioration is not how much productivity was lost, but how long it stayed low in comparison to a matching baseline. As a result, the decreased production should be observed prolonged enough to be regarded as a persistent decrease below the baseline.

Degradation is defined as a divergence in production from its potential

The deterioration and its causes at a local scale were verified on the ground. The challenge remains as to how deterioration can be recognised and described at the regional level, leading to a worldwide evaluation of large-scale land degradation in order to determine the geographic extent of global degradation. Clearly, a time series of aerial or satellite photos is necessary to prove degrading persistence. The next key difficulty is determining how to tie a persistent productivity level to a baseline or reference value in order to determine whether the persistent condition is one of decline. One approach is to utilise the same NPP-related NDVI map (such as the one used by the WAD team) for both extracting the needed baseline and qualifying any other observed NPP values in terms of their deterioration state in respect to the reference value (Prince 2004). A broad region can be divided into homogenous sections composed of grid cells (pixels) with similar climate, soils, and plant community structure but not necessarily the same human effect. This may be accomplished by using plant, soil, and rainfall data, as well as slope and aspect landscape maps.

The signals collected by the satellite sensor are then normalised (the highest NDVI value is assigned a value of 100%). This maximum NPP value for each land class is used as an estimate of the baseline or reference value, indicating the potential NPP for that land class, with all pixels having the same plant type, soil type, and rainfall regime. As a result, this value may be viewed as the potential value for that land type, acting as its baseline or reference. Any other normalised NPP values in that land class can be compared and scaled as a percentage of this value of the class potential.

This technology, known as Local NPP Scaling (LNS), is used to quantify land degradation in Zimbabwe, which may then be upscaled to estimate the geographical extent of global land degradation. Based on maps of Zimbabwe's land cover and rainfall, the country's whole land surface was classified into land classes based on plant type and rainfall. For each pixel, the percentage decrease from the potential NPP was determined. It is worth noting that areas of same colour in the generated map do not always correspond to areas with identical NPP. Rather, they have the same potential NPP but may have different absolute values depending on the plant type/rainfall regime of the land class to which the pixels in these areas belong.

Despite the sources of degradation have not been explored on the ground, the bulk of degraded areas in Zimbabwe are overcrowded community lands that are known to be severely deteriorated. Privately held farms, locations with little population density, and presumably properly maintained rangeland are the least damaged. Whilst the LNS approach of measuring deterioration has not yet been utilised to assess land degradation on a worldwide scale, it is instructive to consider its potential by comparing it to the results of existing global evaluations when applied to Zimbabwe. The GLASOD evaluation based on ground measurements of soil status is thus fairly comparable with the LNS estimate of NPP seen from space, despite its apparent inadequacies. Also, regions rated as "slight" and "moderate" deterioration by GLASOD are classed as "moderate" and "high" susceptibility by the NRCS vulnerability assessment. It is projected that the scope of sensitive places will be greater than the level of deterioration presently occurring. Additionally, when the predicted population effect is included, these locations are of "high" and "very high" desertification danger. The MA desk study assessment results, on the other hand, differ from those of all other assessments, including the LNS, despite the fact that the MA desk study is the only worldwide assessment that incorporated remote-sensing vegetation data in its work.

Trends in deterioration evaluation

The project's initiators were conscious of the necessity to detect trends rather than just participate in the existing condition of land degradation. Trend detection was a component of the GLASOD methodology, which recommended assessing deterioration patterns over the course of 5-10 years between 1980 and 1990. This, however, did not occur due to a lack of controllable data and the short time frame given for this study ("Politically, it is necessary to have a decent quality assessment now rather than a very excellent quality assessment in 15 or 20 years,". Similarly, the MA Desk Study sought to assess trends. This study was titled "Synthesis of the key areas of land-cover and land-use change", and it tried to discover regions with a tendency of environmental deterioration between 1981 and 2000 (Lepers et al. 2005). This method was effective for detecting global deforestation and farmland extension trends, but not for detecting desertification changes. This is because none of the data sets available for the desk study spanned the whole 1981-2000 period, and hence the final outcome of the research did not include information on when the land was degraded, either within that era or previous to it.

Methodology for Rain Usage Efficiency

Despite global land degradation patterns have not been analysed, appropriate approaches have recently been created and are actively being developed for this purpose, with already accessible applications at the local scale. The main impediment to identifying a trend in land productivity, particularly in drylands, is the drylands' heavy reliance on rainfall, along with the drylands' high inter-annual rainfall variability. They preclude distinguishing between human-induced and rainfall-induced variations in NPP. Using the Rainfall Use Efficiency (RUE) ratio and tracking its behaviour over a period of time to investigate the existence of a trend is a straightforward technique to adjust for the influence of rainfall. Using the RUE approach, it was discovered, for example, that over the period 1982-1990, which included the terrible 1984 Sahel drought, there was a tendency of RUE rise rather than decline in most Sahelian locations. This led to the conclusion that the Sahel's diminished output was not due to "desertification" in the sense depicted by GLASOD.

This is a response to decreased precipitation, not to human activity. The "desertification" of the Sahel appears to be a one-time event rather than a long-term decline in land productivity. This assertion was supported by a longer-term remote-sensing investigation, which indicated that the Sahelian NPP is robust to the relatively uncommon severe droughts and is presently recovering from the 20th Century Sahelian assault. The RUE approach has also been implemented into a Sub-Saharan African land degradation monitoring system, which monitors soil erosion as an output of a surface runoff model driven by rainfall data. This technology is said to have the capability of identifying and tracking trends in land degradation. Yet, despite its apparent strength of discrimination, the RUE methodology's trustworthiness has been called into question by the discovery of a substantial negative correlation of RUE with rainfall, for example, $r = -0.82$ for South Africa. As a result, RUE may not remove the influence of rainfall variability on specific years' primary output, and so, despite its efficacy for identifying deterioration, it may not be beneficial for detecting degradation trends.

The approach of Residual Trends

The Residual Trend (RESTREND) approach for finding trends employs rainfall but is not rainfall-dependent, and it is based on an examination of the residuals of the productivity-rainfall connection across time for each pixel in the region investigated for detecting deterioration trends. Hence, the RESTREND algorithm takes as inputs NDVI and rainfall data for a certain time series. They are used to create a regression line between sumNDVIs and rainfall. If this regression is significant, the regression line's residuals are generated and shown against the time series.

Significant regression shows a deterioration trend, the sign of the trend indicates whether it is positive (i.e. effective rehabilitation of degraded regions) or negative, and the slope of the regression line (i.e. the size of the regression coefficient) represents the magnitude of the trend. Thus, whereas the current state of the land and the severity of its degradation are expressed by the percentage deviation of productivity from potential productivity, the degradation trend is expressed by the sign and size of the coefficient of regression of the NPP-rainfall residuals on the time-series for which the trend is established (which stand for the direction and slope of the regression line, respectively).

This approach was utilised to discover and quantify degradation patterns in South Africa, where they may be linked to the intrinsic degrees of aridity in the country's various regions as well as areas of human influence typical of past homelands during the examined era. Likewise, statistics from a country-wide rangeland monitoring programme, the South African National Report on Land Degradation, on the rate of change in rangeland condition of magisterial districts from 1989 to 1999, were consistent with the RESTREND findings. Notwithstanding disparities in geographical scales between the two assessments, this is the case.

Given the promising findings of the South African investigation, it appears that the RESTREND approach may detect deterioration tendencies. Notwithstanding the observed relationships between dryland type and human effect, the specific reasons of negative trends cannot be completely understood when this strategy is used alone. Field surveys are necessary to elucidate characteristics and processes that are not always observable with satellite data alone. This RESTREND approach, on the other hand, has already created multiple preliminary versions of maps showing global land degradation patterns, which are now being tested and improved. (Personal communication, S. D. Prince. Land is a component of Mother Nature that serves as infrastructure for much of life on Earth, yet its operation is under the control of humans. Monitoring and assessing the states and trends of services offered by land when used by humans is so critical. With surging populations and an expanding human imprint on the earth's surface driving globalisation, there is an increasing need, knowledge, and desire to assess the situation of global degradation, rather than simply that of national or local areas. Yet, the praiseworthy efforts undertaken so far to analyse where and when on Earth land cooperates with people, and where, when, and why it is exploited and hence betrays them, have been challenging. As a result, we don't even have a clear response to the issue of how much of the world's land is degraded, much alone what the patterns of degradation have been in the past and what they are now.

The definition of land degradation as a consistent deterioration in the supply of the principal land service - primary production - is a significant conceptual step forward. The use of remote-sensing sciences to assess the states and trends of land degradation, particularly through the remotely sensed assessment of vegetation functions, is another step forward. Hence, the use of remote sensing for tackling the persistence of land productivity declines holds the most potential for future global assessments. Methods such as LNS and RESTREND, which distinguish productivity from rainfall effect and thus, by default, implicate human impact, must be validated through field studies and other evidence provided in this chapter) and upscaled to support not only local but also global insights.

It should be noted, however, that persistence does not imply irreversibility; that is, it is unknown whether the productivity of land that has been properly identified as degraded, and explicitly so due to human impact, can recover once the impact has been removed or rehabilitative actions have been taken. This would only be revealed by measuring trends on both a local and global scale, utilising approaches such as RESTREND and others yet to be established for example, by the LADA project, Lantieri no date. Since approaches such as the RESTREND may identify both degradation and rehabilitation patterns, examining land degradation trends will be useful in determining the efficacy of strategies for "combating desertification" in the drylands and addressing land degradation in the non-drylands. Further developing and advancing tools for assessing trends in land degradation at the local, regional, and, most importantly, global scales is critical for effectively, reliably, and, most importantly, impartially evaluating UNCCD projects "combating desertification" (such as the implementation of National Action Plans) and projects addressing land degradation and sustainable land management (e.g. projects conceived and supported by the Global Environment Facility). Hence, detecting patterns gives both early warning for land overuse and the failure or effectiveness of preventative or restoration efforts.

Status and Trends in Land Degradation in Africa

FAO (2002) defines land degradation as the loss of land's productive capability as a result of soil fertility, soil biodiversity, and natural resource degradation. As noted in many studies, the African continent is significantly endangered by this phenomenon. As a result, Africa accounts for 65% of the world's overall widespread agricultural degradation. According to the World Bank, land degradation affects at least 485 million Africans, and the continent bears a US$9.3 billion yearly cost as a result of this occurrence. Many agricultural and non-agricultural soil uses are identified as having a significant detrimental influence on African lands, including a lack of proper land use. Ignacio Tourino-Soto and Lamourdia Thiombiano planning and misuse of natural resources by landholders, particularly impoverished farmers. Demography growth, conflicts and wars with expanded refugee settlements, inappropriate soil management, deforestation, shifting cultivation, insecurity in land tenure, variation in climatic conditions, and intrinsic characteristics of fragile soils in diverse agro-ecological zones are among the main causes of land degradation in Africa.

Assessing Africa's Land Degradation Trends

Despite its importance, there are little precise and up-to-date statistics on the extent, intensity, and trend of land degradation at the continental level. As a result, the purpose of this work is to evaluate the progress of land degradation using existing data in four steps. Agro-ecological zone, soil, and land use system diversity:

Shows the key characteristics of these agro-ecological zones in terms of land use and soil variability. The variety of agro-ecological zones and land use is great, as is the heterogeneity of soils and landscapes. It is vital to remember that: z a desert like the Sahara, in addition to "hosting" most of the shifting sand dunes, also provides aeolian material across the Sahel. Z The existence of historic ergs (sand dunes) that are exploited as agricultural areas distinguishes dry and semi-arid zones. For millennia, these lands have been kept fertile by a collection of 15 technologies, including the expansion of organic manure. Z As an alternative to shifting cultivation, integrated crop and animal production is gradually being established in arid zones. Soil cover degradation caused by altering agricultural techniques is severe in sub-humid zones. Old woods are found in humid zones. According to FAO, between 2000 and 2005, wood extraction and other types of mismanagement resulted in a net loss of forests of more than 4 million hectares each year. Z The effect of climate change is illustrated in Highlands such as Kilimanjaro by a reduction in snow area, and most ecosystems are threatened. Z the Mediterranean embraces specific zones such as the extreme northern and southern parts of Africa, particularly the coastal areas of Algeria, Egypt, Libya, Morocco, and Tunisia.

Soil loss estimates

The observed substantial geographical diversity in the extent and trend of the degradation process throughout Africa's numerous agro-ecological zones and river basins might be highly related to the behaviour and level of resistance of soils and their surrounding environment. For example, the findings of numerous field research demonstrated a considerable variability of soil loss based on agro-ecological zones. Soil loss in semi-arid zones is 10 times more than in humid zones. This figure should be paired with data on run-off, which is 16 times greater on bare degraded Sahelian soils compared to low run-off in humid zones with better structured soils. Nevertheless, overexploitation of Ferralsols in humid zones resulted in excessive runoff and soil loss on the deteriorated Terre be barre in Benin and Togo on the West coastal water unit. The substantial geographical heterogeneity of land degradation according to agro-ecological zones and river basins demonstrates the possible role of climate elements in the process. Water and wind erosion are key elements affecting over 80% of the total lands in the region, causing deterioration of various forms.

Soil crusting in the Sahelian zone significantly increases run-off and sheet erosion, which is estimated to be 55.6 cm year-1 on denuded soils. In Nigeria, total soil loss due to water erosion is estimated to be up to 30 million tonnes per year. Wind erosion contributes significantly to soil movement in semi-arid and dry zones. Based on the use of a new type of soil catcher named "KATSOLS" in the Sahel zone of Burkina Faso, the transport of aeolian material was estimated to be up to 329 t ha-1 year-1, with 60% of this total amount obtained from June to August at the beginning of the rainy seasons when storms begin with wind speeds greater than 10 ms-1.

The severity and growing scope of land degradation from humid zones to dry and semi-arid areas as a result of the progressive interrelationship and cumulative effect of water and wind erosion. Delhoum et al. emphasised the need of taking this interrelationship into account when analysing land degradation processes, particularly in semi-arid and arid zones. According to the agro-ecological zones, increased soil temperature and more frequent droughts and floods are projected as a result of climate change. As a result, there appears to be a tendency towards the spread of land degradation across the continent, particularly in relation to rising temperatures.

Mismanagement of the interrelationship between agricultural and non-agricultural areas leads in a high tendency of fertility transfer. Grass and organic matter taken from "common lands" are transferred to agricultural areas to boost production. The loss of soil organic matter due to land degradation varies at the agro-ecological and river basin levels. The kind of original organic matter in the soil, the amount of soil exploitation, and eventually the severity of the land degradation process are all possible deciding variables. For example, the amount of organic matter lost from damaged "Terre de barre" in Benin's humid zone is 16% more than in semi-arid zones, and 50% higher in sub-humid zones than in dry parts. From a land management standpoint, it is crucial to note that farmers are gradually investing in their farms to preserve output levels through soil fertility management and soil and water conservation methods. Composts and organic manure, mulching techniques, agro-forestry, stones and earth bunds, rock dams, vegetation strips, and "zai"1 techniques, among others, are used to save soil and water and restore degraded areas. These efforts considerably contribute to the expansion of bright spots, as described by FAO.

Land degradation, defined as the reduction and loss of soil functions, is becoming increasingly problematic across the world. Agricultural output and terrestrial ecosystems are increasingly threatened by land degradation. The major causes of land degradation are unreasonable human actions and land use practises. Desertification is characterised by the United Nations Convention to Combat Desertification (UNCCD) as "land deterioration in arid, semi-arid and dry sub-humid areas arising from multiple reasons, including climatic fluctuation and human activity". Desertification may cause soil erosion, decreased soil productivity, and biodiversity loss, as well as hasten the process of environment degradation in the future. Desertification aggravates poverty and political unrest.

Asia is the world's biggest continent. The Asia Region covers around 44 million km2, accounting for 29.4% of the world's total land area. Drylands cover the most land area in Asia. Desertification is most prevalent in Asia's arid and semi-arid regions. Overgrazing, overexploitation of water and land resources, overcultivation of marginal lands, and the fast rise in population, 90% of which lives in arid, semi-arid, and dry subhumid areas, exacerbate resource management policy failures. Desertification has risen to the top of the list of global concerns, as seen by the number of international meetings and treaties, most notably the UN Convention on Climate Change. Preventing desertification from spreading is an essential part of human-nature coexistence. Desertification management is a global obligation and duty. Implementation that is fruitful and successful would undoubtedly facilitate- 56 Hong Ma and Hongbo Ju state Asian countries' efforts to battle desertification, enhance Asia's natural environment, and contribute to long-term growth. The Asian Regional Thematic Programme Networking on Desertification Monitoring and Assessment, abbreviated as TPN1, was founded in July 1999 in Beijing, China, guided by the rules of the UN Convention on Climate Change.

China has been designated as the host nation for TPN1 operations among member countries

The Chinese Academy of Forestry hosted the TPN1 Working Group Conference on Benchmarks and Indicators on Desertification Monitoring and Assessment. The group decided on a suggested shared set of benchmarks and indications for comments, ideas, and future development. The suggested indication system has four components: Pressure indicators describe natural and man-made driving factors that alter the state of environmental assets and contribute to desertification. They will be used to analyse desertification trends as well as to provide early warning. The status of natural resources, particularly land, is characterised by state indicators. Desertification impact indicators will be used to assess the impacts of desertification on people and the environment. Application indicators will be used to evaluate the activities done to mitigate desertification and the effects on natural resources and humans. Most TPN1 member nations provided feedback on the Benchmark and Indicators proposal between the end of 2001 and early 2003, as shown. The MODIS Image of the Asian Area. In Asian Land Degradation 57 the plan was initially changed to incorporate some of the comments and recommendations.

The proposed Asian Regional Desertification Status Map, based on the characteristics of desertification and the benchmarks and indicators system, will assist users at the national, regional, and international levels in understanding the causes and improvement of desertification, as well as ecosystem vulnerability to desertification and land degradation. Applied studies of satellite pictures in desertification monitoring and evaluation are being undertaken using remote sensing techniques in the Asian area. The first draught of Asia's desertification status map had been finishe6. This map is a valuable and visual reference for desertification forecasting and planning preventative or combative actions against it by depicting the origins and dynamics of desertification in relation to the process itself and the environmental responsibility to desertification. Remote sensing techniques, the use of geographic information systems (GIS), and global positioning system (GPS) technological development have all offered significant technical support for monitoring and assessing land degradation. They also served as early-warning markers of desertification changes.

Several nations and institutions have contributed to the TPN1 activities' execution. All of these efforts and outcomes will help to battle desertification, a severe threat to our world. India built a nationwide network, and regional action plans for the Asian area were developed. The goal is to increase the current capacities of. Asian Region Desertification Status Map. Member nations in the Asian area should take appropriate steps to counteract desertification, according to Hong Ma and Hongbo Ju. The desertification status map was created at the national level using satellite data. On a vast area and on a huge scale, a system for monitoring and assessing desertification using remote sensing has been created.

An extensive research on desertification monitoring and assessment was conducted by Japanese experts. They have created tools for tracking biological land production and assessing sustainability. The social and economic components were incorporated as a key indicator for analysing and calculating potential land production using satellite remote sensing and GIS technology. Mongolian scientists gathered and analysed vast amounts of data on relief, soil type, erosion, salinity, vegetation cover, biomass and fodder resources, ground water level, wind speed and frequency, dust storm days, precipitation, drought duration, fauna and flora species, and produced the desertification map. The map reveals that a substantial portion of the nation has moderate to severe deterioration. To acquire data from large regions, remote sensing data were utilised to create a land cover map from NOAA NDVI composite data, and GIS-based databases on desertification were constructed for monitoring purposes, incorporating all of the previously described data. In Iran, activities included protecting plantations and irrigation systems, minimising the impacts of air pollution and dust storms, and monitoring and managing droughts.

Drought conditions are monitored using satellite photography, vegetation indices, and other methods. Large-scale actions have been conducted to mitigate desertification.

Asia's Land Degradation Situation and Trends

Asia faces several obstacles in combating land degradation and desertification. Wind erosion, water erosion, soil salinization, a big population, pasture deterioration, and vegetation degradation as a result of overgrazing, and biodiversity losses plague Asian area countries. These issues reduce land productivity, increase the frequency of floods, droughts, and sandstorms, and cause eco-environmental degradation across wide regions of the Asia region (Winslow et al. 2004).

West Asia

West Asia is witnessing one of the most dangerous levels of environmental deterioration and desertification. Most shifting sand dunes are incapable of supporting plant life. West Asia has a distinct mediterranean climate. Desertification has been promoted by wind erosion, water erosion, soil salinization, a big population, and low productivity.

Asia's Land Degradation Situation and Trends

The majority of marginal lands in West Asia are permanent pastures covering 1.35 million km2 and are deemed to be in danger of desertification in 85% of cases. Natural vegetation clearance and unsuitable agricultural practises are rapidly deteriorating and depleting precious and scarce biological, soil, and water resources. This region is thought to have one of the world's greatest yearly population growth rates. This varies from nation to country, but on average it is greater than 2.4%. It is not surprising that population growth, in particular, may force additional extension of farmland and permanent pastures at the expense of forest and woods. Moreover, shifting consumption patterns and lifestyles, which have resulted in increased food demand, have expedited land degradation in this dry climate. Saudi Arabia is the largest nation in the region of West Asia. The bulk of Saudi Arabia is desert, and the ecology is deteriorating. The hard environment, fragile ecosystems, and limited water supplies and fertile lands define the region. Desertification was remained one of the biggest environmental challenges in this area at the end of the twentieth century, despite national, regional, and international efforts to prevent it and reduce the consequences of drought and desiccation.

Iran, which is located in the dry zone, features both plateaus and mountainous areas, with the Iranian plateau being the most populous. The arid basin in the east accounts for one-third of the overall land area. According to statistics obtained in November 2005, Iran's rangelands number around 90 million hectares, with overgrazing being the primary source of deterioration. Iran contains 286 wetlands, and the most major threats to wetlands have been agricultural drainage and reclamation, as well as water supply diversion for irrigation. Iran has 7.4 million hectares of irrigated agricultural land. Soil salinity affects around 60% of Iran's irrigated agricultural area in varying degrees. Deforestation often results in large-scale erosion, soil nutrient loss, and the land mass becoming barren and sterile.

South Asia

South Asia's population density is substantially higher, resulting in severe land constraints. Desertification was accelerated by intensive overgrazing, marginal farming, and fast-moving sand dunes. The arid lands encompass a huge chunk of India. Deforestation, soil erosion, overgrazing, and desertification have long been a source of worry in India, hurting the way of life of its people. The problem is more acute in the dry plains of the country's northwest, particularly in desert expanses.

The Thar Desert in western India is the largest desert in South Asia. The vast part of the land is desolate, and strong dust storms are huge calamities. The large and rising population is putting a pressure on natural resources, and residents have been migrating in pursuit of pasture life. The Thar Desert is expanding by 100 ha per year, inflicting 60 Hong Ma and Hongbo Ju damage to about 13,000 hectares of agricultural land and pastures in India and Pakistan.

Asia Central

The harsh dry terrain countries of Central Asia suffer widespread drought and desertification risks, with inadequate means to tackle them. The Aral Sea Basin changes are widely recognised as one of the most catastrophic examples of environmental deterioration in the twentieth century. In 1960, the Aral Sea in Central Asia was ranked as the world's fourth biggest inland sea by surface area. It was also one of the most fertile areas on the planet. Its area had shrunk by 54% by 1992. Lake levels had plunged by more than 16 metres, and volume had dropped by 75%.

The sea bed eroded into two distinct portions in 1989. A programme to establish cotton self-sufficiency diverted large volumes of water from rivers running into the Aral Sea. The desiccation of the sea zone sparked additional processes such as salinization and contamination of streams, and the dry sea causes severe sand storms that take up and spread millions of tonnes of salt.

The bottom of the dry sea has developed a salt shoreline covering roughly 36,000 km2. Desertification has grown swiftly, and approximately 80% of the old Aral Sea's northern region now desertified. Progressive desertification has lowered pastureland production and ruined woods and meadows.

The abundant plantation, 15% of grassland, and enormous woodland resources surrounding the Aral Sea have been devoured, and the fish in the Aral Sea have gone off. The Aral Sea situation has not only perplexed Central Asia, but has also triggered a global ecological disaster. Mongolia is a landlocked nation in Central Asia with a harsh continental environment (poor precipitation, large daily and seasonal temperature changes, and powerful sand and dust storms), which exacerbates the danger of desertification.

The major cause of desertification in Mongolia is land degradation caused by inappropriate use of land, water, and forest resources, overgrazing, chopping trees and bushes for firewood, and farming in the absence of natural conditions. Rodents, grasshoppers, and goats completely destroy plants. They contribute to desertification. China is one of the countries impacted by desertification, which has a wide distribution and negative consequences. China's exploitable land resource is quite restricted. According to the State Forestry Administration's 2005 "Chinese desertification report," desertification affects about 2.64 million km2 or 27.46 percent of China's total land area. The Gobi Desert, which runs across southern Mongolia and northern China, increased by 20,000 square kilometres, according to China's Environmental Protection Administration.

Rising atmospheric carbon and climate change

Experts believe that global climate change, such as global warming, is caused by rising amounts of greenhouse gases in the atmosphere and is having an influence on the Asian region's growing droughts and deserts.

Many people's living situations have deteriorated

With increased unsustainable resource usage, land degradation leads to additional deterioration of land resources, which leads to rising poverty and worsening living conditions for many people. Desertification has affected around 35% of Asia's arable land. Desertification and dry conditions affect over 1.3 billion people, or 39% of the Asian region's total population. Desertification is the destruction of ecosystems on the earth's surface.The study of land degradation is a discipline in which natural and social sciences intersect and interact. The above-mentioned land degradation status research set the groundwork for analysing current land degradation trends in the Asia Area. Asia is one of the regions most impacted by desertification, with more than half of the dry areas, particularly in Central Asia, being particularly vulnerable. According to research data, desertification has only been limited to a certain level. In actuality, it is still spreading on a big scale, and many difficulties remain unresolved.

The use of satellite remote sensing technologies for large-scale desertification monitoring and assessment is in its early phases. In establishing economic and technical initiatives, there is a need to protect ecosystems from further deterioration and to restore the productivity and natural beauty of ecosystems that have been impacted. As a result, more precise, timely, and systematic monitoring of desertification and future prediction trends is required. This will allow for the deployment of stronger environmental measures to manage ongoing land degradation, rehabilitate damaged regions, repair ecosystems, and maintain a balance with the sensible use of natural resources.

Certain advanced space technology have been successfully adopted in industrialised countries. The international community has long acknowledged the need of global collaboration in combatting desertification and alleviating the consequences of drought. To achieve the objective of combatting desertification in Asia, there is a need for more technological development and collaboration. Before the seventeenth century, Latin America was underpopulated. It was distant from the world's most populated areas, such as China, Africa, and Europe, where the earliest human concentrations arose. This continent was distinguished by civilizations that were geographically separated and lived in relative harmony with their natural resources. Demographic expansion began slowly, about 500 years ago, after Europeans arrived to occupy this region. As a result, this continent retains the majority of its original genetic resources and biomes.

South America possesses the world's most extensive genetic resource reserve. This region is home to around 40% of all known living species and has a substantial reserve of agricultural land and fresh water. In its major tropical and temperate biomes, this region supports around one-third of the world's woods. Certain sections of the Amazonian mass and temperate sub Antarctic forest are among the least damaged ecosystems that remain pure. The great marine biodiversity of Antarctic seas is widely recognised. Despite its genetic diversity, significant deforestation has mostly impacted coastal habitats.

CHAPTER 3

SOILS AND IMPLICATION

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The region's agricultural potential is projected to be 576 million acres (GEO 2002). Arid or semiarid regions cover around 24% of the Americas. The employment of poor farming techniques is the leading source of soil degradation. Land degradation affects around 45% of croplands in South America. In Mesoamerica, these rates are even more striking, reaching 74% of agriculture. The development of croplands into previously wooded regions is the primary cause of deforestation in the Amazon. After a few years, the soil deteriorates and crops are abandoned in favour of permanent pastures. Soybean cultivation has been the primary driver of agricultural border growth in northern, eastern Paraguay, and central Brazil.

Desertification and droughts are major threats to the arid areas

These phenomena have huge social consequences, causing millions of people to migrate to cities and putting social strain on cities. This is one of the causes of rising crime and political unrest in many nations. Irrigated areas cover around 15 million acres, with the majority of them exhibiting signs of soil deterioration. Around 20% of the physical surface has already been eroded.

Biodiversity

The region is home to 40% of the world's plant and animal species. The biota of all countries is under peril. 103 bird species are endangered in Brazil alone. With 64 species apiece, Peru and Colombia are ranked fifth in the world. One-third of Chile's vertebrates are endangered. Brazil also contains 71 endangered animal species (the fourth highest in the world). More than half of Argentina's animals and birds are likewise endangered. Bolivia's highlands, which reach elevations of 3800 metres around Titicaca Lake, enable intense cultivation of annual crops (potatoes, quinoa). Stocking rates of Lamas and Alpacas are frequently greater than the carrying capacity of degraded grasslands, accelerating vegetation regression and soil deterioration. Water and wind erosion are the primary causes of soil degradation in the Highlands and mountains. The excessive extraction of water from wetlands causes desiccation, threatening the integrity of rich, biodiverse, and unique ecosystems containing more than 70% indigenous species.

The Valdivian Forest in Chile is one of the Southern Hemisphere's remaining large temperate rainforests. Just 18% of the original Alerc forest remains after a century of wood exploitation. This is the world's second longest-living species (trees aged more than 2500 years). At the moment, it is highly likely that this rare species is threatened in her key region and forest structure, making her conservation impossible. At the moment, the wet tropical forest is being removed, primarily by fire, to make way for annual crops and pastures. In just one year, more than 12,260 km2 of Amazon rainforest were destroyed. The Mata Atlantica vegetation, considered a significant genetic reserve, has been reduced to tiny spots on Brazil's south-eastern coast. South America accounts for 610,730 km2 of total tropical deforestation decade-1, whereas Central America and Mexico account for 111,200 km2 decade-1. These numbers show that the total rate of tropical deforestation is greater than the rate of deforestation elsewhere in the globe.

Water

The Amazon, Orinoco, So Francisco, Paraná, Paraguay, and Magdalena rivers account for more than 30% of continental runoff in South America. Despite this, two-thirds of its land area is dry or semi-arid. These areas are in central and northern Mexico, northeastern Brazil, Argentina's west and south, Northern Chile, Bolivia, and South Western Peru. If irrigated, dry and semiarid areas typically offer significant agricultural potential 68 Fernando Santibáez and Paula Santibáez. Irrigation now covers 697,000 km2, accounting for 3.4% of South America's land area. Due to poor irrigation system management, irrigated regions suffer from salinization and waterlogging.

Ecosystems and human drivers

Human drives are sometimes referred to as natural resource pressures. Human strain on soil is mostly caused by improper farming practices and intrusions on natural ecosystems to extract products and services. As a result of these human manipulations, natural equilibriums are disrupted, sparking a series of deteriorating processes. Food, raw materials, and energy production, as well as mining and industrial activity, urbanization, tourism, and other human activities, all put a strain on natural resources, either directly or indirectly. All of these human acts cause natural systems to lose mass, energy, or information, frequently leading to permanent simplicity. Human activities on natural systems tend to accelerate processes that waste energy, lowering the store of internal energy and the stability or complexity of the system.

Natural systems are capable of absorbing minor transitory imbalances or stresses and restoring their structural and functional integrity on their own. Its resilience enables ecosystems to remain unchanged over long periods of time despite changes in their surroundings. Additionally, natural systems have become stronger as a result of the slow and subtle climatic changes that have happened through time. When imbalances exceed the system's resilience capacity, changes become irreversible, and the system cannot recover on its own. In such circumstances, the system has lost information or critical components that are unrecoverable in human time scales. Almost any component of a natural system may be described as a balance between the factors that drive deterioration and those that drive recovery. The crucial point is to understand the population's involvement in the intake and emission of matter, energy, and information to and from natural systems.

Natural systems with lower resilience capability are more vulnerable. In general, the most complex systems, or those that must complete longer cycles, such as temperate forests and wetlands, are more susceptible. In many situations, the reproduction of plant and animal species is dependent on delicate balances that, when disrupted, might limit the spawning of new generations that could ensure the stability of an ecosystem. The mere removal of a plant species might jeopardise the life of an animal species that depends on it, which in turn can jeopardise the survival of predators, sparking a cascade of actions whose eventual effect is impossible to predict. Human demands are difficult to describe with a single metric. They are frequently the outcome of a combination of derived elements from human acts on the environment. Moreover, one action might have many impacts on distinct environmental components at the same time, exerting multiple pressures over a period of time.

Desertification

Desertification is the simplicity and loss of the natural balances of ecosystems characteristic in water-stressed regions, affecting the people' quality of life. The resilience of dry climatic ecosystems is often great. Yet, they are deemed vulnerable due to high levels of water stress that impair vegetation communities and inadequate soil protection as a result of reduced plant cover. The exploitation of plant biomass for pasture or fuel reasons is one of the most significant human interventions that initiates or worsens the desertification process. This diminishes plant cover, making soil more vulnerable to the eroding action of climatic conditions. Soil erosion affects soil fertility and water holding capacity, triggering a cycle of events that, through positive feedback, worsens ecosystem decline. A cause-and-effect diagram for this line of events. All of the processes that contribute to desertification are slow and ongoing. Although deterioration of environmental components occurs in general with some simultaneity, under specific management settings, and depending on the character of each ecosystem, certain components may decline quicker than others. This distinguishes each degrading condition from the others.

Current Climate Trends

Land degradation is caused by a mix of human and climate factors. Throughout the last thousand years, climate has caused significant terrain changes. Climate patterns may be seen over most of the continent. From the mid-1970s, temperature data in the tropical Andes reveal a considerable warming of roughly 0.33°C each decade. Between 1960 and 2000, the minimum temperature at Chiclayo, Peru's north coast, rose by 2°C. In Chile, similar patterns were seen. Similar tendency has also been documented in the high plateau area of extreme southern Peru, where the lowest temperature has increased by 2°C between 1960 and 2001. Temperature changed quicker in the twentieth century than in previous centuries, with a significant acceleration in recent decades.

In the Western and Eastern coastal regions of South America, daily time series revealed no consistent variations in maximum temperature whereas substantial trends in lowest temperature were discovered. Rainfall on the South Western Pacific coast has showed a strong decreasing trend during the twentieth century. A contrasting tendency has been noted along Argentina's and Southern Brazil's Atlantic coasts, as well as in many other places of the world. In the final half of the twentieth century, mean annual precipitation in the humid Pampa rose by 35%. Climate variability appears to be growing, making extreme climatic events such as drought and flooding more common. Because of deforestation, which reduces vapour transmission to the sky, the Amazonian basin's water regime is becoming increasingly drier. One of the rare examples of evident relationship between forest cover and mesoclimatic regime is the Amazonian rain forest.

Overall, the continent is experiencing a significant loss of permanent ice bodies, primarily Andean permafrost and glaciers, which have shifted their lower fronts higher by 300 m or more in a century. Several glaciers in southern Argentina and Chile have receded hundreds of metres, reducing their thickness by 100 cm every year. Patagonia's glaciers have receded by Climate agressivity and unpredictability, soil type, vegetation resilience, and landforms all influence ecosystem vulnerability. Ecosystem vulnerability, economic resources, access to technology, and social structures and help networks all contribute to social vulnerability.

Because of the existence of major human populations, complex landforms, and a dynamic hydrological system, the Andes Highlands are extremely vulnerable to climate fluctuations. Avalanches and landslides are a constant hazard to tiny settlements and agricultural fields. Precipitation is concentrated in a short rainy season of 3 to 4 months in Mediterranean climates, which have a lengthy dry spring and summer. As the first rains fall, the dry bare soil is heavily eroded, resulting in huge sedimentation of rivers and lower lands. This condition was aggravated in the previous century by soil denudation, which replaced thick chaparral and savannas with degraded annual herbs that are unable to buffer soil from water and wind erosion. The Andes piedmont has been urbanised in certain regions near cities, causing quick runoff and floods after heavy rains.

The continent's major biomes are susceptible to a variety of natural and human causes or pressures. Human-caused pressures are determined by population density and the productive use of natural resources. Natural pressures are mostly caused by climate change, which forces ecosystems to adapt to new climatic circumstances while also producing more unfavourable conditions for soil conservation. Typically, human and natural drives interact negatively, making it difficult to maintain ecological integrity. Another aspect of land degradation is ecosystem susceptibility, which may be described as the ability of natural flora, animal species, and the physical environment to resist, absorb, or neutralise an external perturbation without irreversible changes. Various biomes are vulnerable in different ways, depending on their ability to recover from human intervention or natural environmental change.

Soil deterioration has an impact on agricultural land productivity, ecosystems, natural plant cover, biodiversity, and people livelihoods. Land degradation is caused by a variety of factors, including unsustainable farming practises, ecological fragility, human pressure, and a changing climate. Land degradation is the initial step in a lengthy chain of events that impair the integrity of ecosystems, ecosystem services, and the territory's ability to sustain human activities. The El Nio-La Nia phenomena is one example of this. During the El Nio phase, the Pacific water heats by 2 to 4 degrees, causing heavy rains in the Southern Cone, while droughts impact Colombia, Venezuela, Mexico, North Eastern Brazil, and the Amazon basin. Inverse effects are related with the cold phase.

This phenomena, which is the primary source of floods and landslides, poses a serious threat to human communities. Droughts occur on a regular basis, making agricultural investments unfavourable. This El Nio Southern Oscillation (ENSO) is most likely the principal source of climate unpredictability on the continent, making precipitation very dangerous and prompting farmers to turn to low-input agriculture in order to decrease economic risk. This results in marginal agriculture, with low yields and revenue, and, as a result, societal disintegration, which is frequently the principal reason of enormous migrations. This has occurred in northern Brazil, northern Argentina, northern Chile, and Mexico.

Land degradation is the final outcome of a long chain of events that began in diverse places. The most prevalent are social exclusion and a scarcity of economic and technological resources. In these conditions, farmers, who are frequently small-scale proprietors, try to save costs by employing simple and vigorous soil cultivation practises, resulting in soil erosion. Mining has historically been a second cause. Metal foundries' high energy demand prompted destruction of vulnerable ecosystems in order to provide miners with fuel wood and charcoal. The third factor was industrial agriculture, which utilised a lot of fertiliser, herbicides, and machines. This combination resulted in organic matter loss, soil compaction, and, after a few years, a worldwide decline in soil productivity. In all situations, a combination of human pressure and climate aggressivity posed a threat to critical ecosystems. Sugarcane farming was the principal source of forest cover reduction in tropical places over the previous three centuries, particularly in the late 18th century, to build unsustainable production techniques. Because of the steepness of the slopes it occupied, most of this area had only shallow and weak soils that are particularly prone to erosion.

As a result, considerable amounts of topsoil were lost in many regions, particularly in Mesoamerica's volcanic soils. Although the most severely impacted regions are no longer under cultivation, the natural vegetation that has recolonized these places has a substantially lower species diversity and biomass than the original vegetation. Low and irregular rainfall generates a persistent water stress in arid and semiarid sections of the continent, resulting in poor stands of sparse plants that provide inefficient protection to the soils from the erosive impacts of rainfall and wind. Because of the complexities of the interrelated interactions between plant ecophysiology and climate, predicting the influence of climatic fluctuations on agricultural yield is challenging. Higher temperatures have a definite detrimental influence in certain cases and a clear good effect in others. Crop behaviour in new climatic situations will be determined by the balance of negative and positive influences. A rise in temperature in frigid areas will almost probably be beneficial, increasing growth rate and biomass buildup. If this event is followed by a decrease in precipitation, the negative consequence will counteract the good shift in temperature regime. The final outcome will be determined by which of the two occurrences prevails. Temperature rises in tropical locations generate circumstances for thermal stress, which is harmful to crops. Simultaneously, greater CO_2 levels will help plants to better withstand these stressful circumstances due to increased photosynthetic rates, which offer more carbohydrates to maintain higher respiration rates.

Global warming is anticipated to accelerate life in all climates, as seen in Pathways to land degradation. The paths of good lands with intensive agriculture and marginal lands with minimal input agriculture diverge, yet the final outcomes are identical. The Agri Deserti is entirely deteriorated terrain that cannot be used for agriculture. Fernando and Paula Santibáez cycles of pest and insects, promoting plant sanitary balance. Similarly, the life cycle of plants will be expedited, lowering the time required for biomass buildup.

This will have a detrimental impact on yields. To counteract this phenomena, cultivated regions should relocate to cooler climes if possible, or adjust sowing dates to coincide with lower temperatures throughout the year. Agricultural production will be fatally reduced in areas where these two scenarios are improbable.

Temperature increases in hot tropical areas will reduce agricultural productivity by slowing the crop growth cycle. Phenology will occur more quickly, lowering the duration of phonological phases; as a result, output of fruits, grains, and plant aerial organs would decrease. Its detrimental impact is exacerbated in the continent's dry climates (NE Brazil, Northern Mexico, Peru and Chile, and Southern Argentina).

In humid tropical areas (Amazon basin, Northern Argentina, and Meso America), increasing temperatures have recently interacted with a more aggressive and erratic precipitation pattern. Coffee and banana crops along the Central American-Caribbean Rivers may face greater stress if climate change causes more storms and heavy precipitation (Campos et al. 1997). Ozone depletion would also contribute to increased UV levels in the southern half of the continent, which will affect the growth of several agricultural species owing to the harmful influence of auxines. One exception is the grapevine, which benefits from increasing UV levels because it increases the synthesis of flavonoids, which improves wine quality.

Global warming will also improve circumstances for the geographical spread of insects and pests. Warmer temperatures hasten reproduction, reducing the time required to complete the life cycle of insects and pathogenic agents. Changes in precipitation regime might boost host susceptibility, lowering predator and competitor numbers.

There is some indication of pest and insect distribution ranges expanding poleward, which might present new hygienic hazards in temperate climates. Its growth is projected to have an ongoing impact on highland and temperate agriculture. The emergence of late potato blight in Central Chile in the early 1950s was one example of this.

Farmers in many places have minimal financial resources and use low-input agricultural practises, leaving them with little capacity to adjust to the changing conditions imposed by climate change. Adaptive capacity necessitates efficient irrigation and water management systems, highly technical pest and disease management, strict control of climatic risks through early warning systems and information systems, adaptation of genetic resources (to change crop seasonality and increase pest and disease resistance), and highly technical pesticide and fertiliser management (to prevent contamination of waters and foods).

Farmers in certain locations may never be able to adjust to these conditions at the appropriate rate. Even minor variations in crop production and productivity can cause major disruption and financial loss in marginal agricultural populations. Farmers are currently in an exceedingly vulnerable position since agricultural product prices are at the lower limit to support output decreases (Figure 2.1).

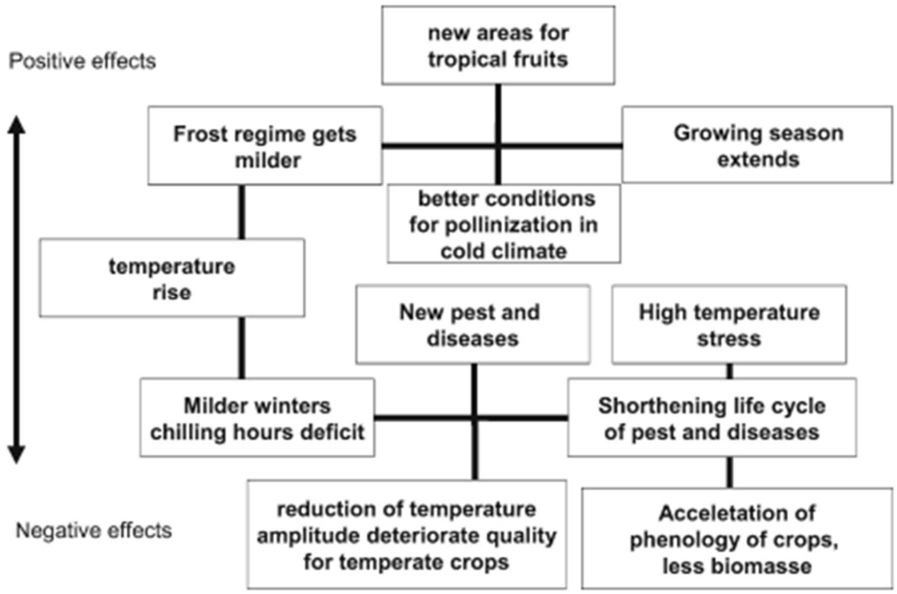

Figure 2.1 represents the Summary of positive and negative effects for crop species of temperature rise.

The predicted net economic consequences of climate change on crops are negative for numerous Latin American nations due to increasing energy, pesticide, and fertiliser prices. Globally, the continent will see significant climate changes throughout its whole region. Changes in South America, particularly in coastal locations, may be tempered by the Southern Hemisphere's large quantity of seas. Despite this, a significant change in the behaviour of climatic oscillations such as El Nio-La Nia is predicted, which will continue to be a driver of climatic variability in practically all continental expansion (Paeth et al. 2006). Isotherm and isohyet displacements are occurring quicker than natural ecosystem adaptation processes; this might pose a serious danger to critical biomes on this continent, particularly the Amazon basin and temperate rain forests. Changes in rainfall patterns, the retreat of ice bodies, and higher evaporation rates might diminish runoff and available water in the next decades. Global warming will compel significant adaptation in agricultural systems, such as improved technology and a shift in crop seasonality. Only modern agriculture will be able to adapt to these new conditions, which will have a significant impact on small farmers who dominate in large portions of the continent. When evaluating these tendencies, certain issues arise: Will we be able to reverse this trend before a true catastrophe occurs? How much will we have to pay to adapt to a changing climate.

The European Commission's approval of the EU Thematic Strategy for Soil Preservation on September 22, 2006, formalised the severity of soil and land degradation processes inside the European Union and its neighbouring nations. The Strategy contains an extended impact assessment that quantifies soil deterioration in Europe, both environmentally and economically, and serves as the foundation for this study. This effect assessment is based primarily, but not completely, on studies by the Commission's Joint Research Centre (JRC) and the Working Groups established to assist the Commission, as well as papers prepared for the Commission in reviewing

Luca Montanarella discusses the economic implications of soil deterioration as well as the economic, environmental, and social impacts of various soil degradation prevention techniques.

According to available data, soil degradation processes have increased significantly in recent decades, and there is indication that these processes will continue to expand if no action is done. Human activity drives or exacerbates soil deterioration processes. Climate change, as well as particular extreme weather events that are growing more often, will have a deleterious impact on soil. Erosion, organic matter reduction, compaction, salinisation, landslides, pollution, sealing, and biodiversity decline are all examples of soil degradation processes that occur in the European Union.

CHAPTER 4

BASICS OF EROSION

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Erosion is a natural process that may be further enhanced by human activity. It is recognised as a severe issue throughout Europe, particularly in the Mediterranean region, but snowmelt erosion occurs in Scandinavian nations and wind erosion is frequent in Central and Western Europe. The following are the main human-induced driving forces: z Soil disturbance, such as ploughing up and down slopes:

1. Z Elimination of vegetative soil cover and/or hedgerows.
2. Z Expanded field size (open fields).
3. Terraces have been abandoned.
4. Z Winter cereals are planted late.
5. Z Excessive stock.

Z Inadequate crop management. Z Improper use of heavy machinery, not just in agricultural and forestry activities, but also during building projects. In Europe, soil erosion is on the rise (EEA 1995). Because accurate estimations are impossible owing to a lack of comparable data, determining the overall area of the EU impacted by erosion is challenging. The EEA calculated that water erosion affects 115 million hectares, or 12% of Europe's total land area, while wind erosion affects 42 million ha, with 2% seriously affected. While assessing the damaged area is challenging, erosion risk has been recommended as an indication of real erosion that may be quantified using prediction models such as PESERA (Kirby et al. 2004). Except for Sweden, Finland, Malta, and Cyprus, where Corinne Land cover data is not available, this model covers the most of the EU25. According to PESERA, more than 10 tonnes (t) ha-1 yr-1 erosion threatens 3.4% of the territory covered by the 21 Member States (1.6 million ha), with 18% (54%) at danger 25% of the land (corresponding to 75.5 million hectares) is at danger of losing soil over 1 t ha-1, and 25% of area (corresponding to 75.5 million ha) is at risk of losing more than 0.5 t of soil ha-1 yr-1. The Mediterranean area is the most afflicted, but there is substantial evidence that other sections of the EU25 are also affected. For extreme weather events, the losses might be significantly greater: for example, in a rainfall in southern Spain, 20 t of soil can be washed off a single acre in a matter of hours. Because natural soil building is exceedingly slow, losses over 1 or 2 t ha-1 yr-1 are deemed irreversible. Because soil is basically a non-renewable resource due to its slow creation, the repercussions of erosion for soil fertility and soil ecosystems, as outlined below, are significant:

Human health issues caused by dust and particulates in the air

SOM, the organic portion of soil (excluding undecayed plant and animal leftovers), is critical for soil biodiversity and plays a significant role not just in soil fertility but also in soil structure, buffering, and water retention capacity. As a result, only the stable fraction of soil organic matter, the proportion that can be turned into humus, is mentioned in this evaluation. Humus is soil organic matter, excluding incomplete breakdown products of undecayed plant and animal leftovers and soil biomass; it has an amorphous form, a low specific weight, and a large surface area. The main ingredients are lignin, protein, and cellulose derivatives mixed with inorganic soil elements. Humus has colloidal features that allow it to increase soil attributes such as structure and porosity, sorption capacity (water, plant nutrients), erosion protection, buffering capacity and plant protection from dramatic changes in pH, and storage for microorganisms.

SOM has a significant impact on the soil's carbon cycle. Soil, in fact, is both an emitter of greenhouse gases and a substantial carbon storage. There are 1,500 gigatonnes (Gt) of soil organic and inorganic carbon in the worldwide soil carbon pool. Additionally, some land management strategies that enable carbon sequestration in agricultural soils have the potential to contribute to climate change mitigation. According to some estimations, this amounts to roughly 2 Gt of carbon each year (Lal 2000). Soil carbon sequestration capacity was projected to be similar to 1.5-1.7% of the EU's anthropogenic CO2 emissions during the first commitment period of the Kyoto Protocol as part of the European Climate Change Programme (ECCP). Simultaneously, climate change will very certainly raise the likelihood of risks owing to more extreme weather events such as floods and heavy rains, as well as higher temperature. This has serious implications for soil biodiversity as well as the viability and feasibility of producing specific crops.

The following are the primary human-caused driving drivers of climate change: z Conversion of grassland to arable land.

1. Wetland drainage.
2. Inadequate crop rotation and plant residue management, such as crop residue burning.

In Europe, approximately 45% of soils have a low or very low organic matter concentration (0-2% organic carbon) while the other 45% have a medium amount (2-6% organic carbon) (Jones et al. 2005). Apart from climate factors, the most important driving drivers are unsustainable human activity. There is no comprehensive and comparative data for the EU25 on SOM content, although methods exist to approximate it. According to these estimates, the problem of soils with extremely low and low SOM appears mostly in the Southern nations, where 74% of soils contain less than 3.4% organic matter, but also in areas of France, the United Kingdom, Germany, and Sweden. The creation of a Common Implementation Strategy (CIS) has been discussed with Member States and is widely seen as positive. Guidance papers would be created in such a Fashion, based on current documents, to aid in risk detection. This might also be a forum for exchanging expertise on risk reduction techniques in order to analyses the measures implemented and enhance the effectiveness of programmes and remedial procedures.

The consequences of SOM loss on soil fertility and soil ecosystems are profound, as explained below. Emission of greenhouse gases. Negative consequences for biodiversity, particularly soil biodiversity. Decreased water infiltration as a result of changes in soil structure, resulting in an increased flood risk. Increased erosion with the aforementioned consequences, including: - loss of fertile soil - loss of soil fertility (due to disrupted nutrient cycles) - infrastructure damage due to excessive sediment load - diffuse pollution of surface water - negative effects on aquatic ecosystems and thus biodiversity- Land use restrictions that impede future redevelopment and reduce the area of fertile and precious soil accessible for other operations (agricultural and forestry production, recreation etc.). Because a decrease in SOM causes erosion, all of the expenses outlined are equally applicable here, but will not be repeated. The following list only includes the expenditures directly related to a decrease in SOM. For a decrease in SOM, the following expenses must be considered:

Any estimate of SOM loss on a European scale is severely constrained by a lack of data and a precise classification for various forms of organic matter. While there is some data on soil organic matter content, there is no consistent Europe-wide data on organic matter losses. Likewise, the influence of organic matter loss on soil production has received far less attention than erosion. The annual on-site costs of SOM reduction (owing mostly to decreasing soil productivity) are projected to be over €2 billion. Concerning the off-site implications of SOM loss, there is evidence that the carbon released from soils has a significant impact on climate change. The yearly costs to society of the carbon emitted annually from soils owing to SOM reduction are estimated to be between €1.4 and 3.6 billion. Some estimates indicate that a result in the same range may be worth at least €3.1 billion per year. Hence, the overall yearly costs of inaction for SOM decrease are anticipated to be between €3.4 and 5.6 billion. Compaction, which causes an increase in bulk density and a decrease in soil porosity, is mostly a subsurface issue.

Estimates of the extent of soil compaction differ. While they all indicate the relevance of soil compaction, there was insufficient data on the actual incidence of compaction, but data on soil susceptibility to compaction was available. According to some writers, around 36% of European subsoils are susceptible to compaction. Some sources state that 32% of soils are very sensitive and 18% are moderately damaged, while others claim that 33 million hectares, or 4% of European land, are harmed.

There were no quantitative estimates of overall expenses available. Indeed, economic data on the effects of compaction are few. In terms of on-site expenses, it has been estimated that surface soil compaction can lower yields by up to 13%, whilst subsurface compaction can reduce agricultural yields by 35% or more in extreme dry or wet seasons (Van-Camp et al. 2004b). Nevertheless, the off-site compaction expenses could not be anticipated at this time.

Salinisation, the accumulation in soils of soluble salts primarily of sodium, magnesium, and nutrients, can occur naturally in low, poorly drained areas in hot and dry climates where surface water collects and evaporates, but it can be exacerbated by human activities, particularly inadequate agricultural land irrigation. The following are the main human-induced driving reasons for salinisation: z inadequate irrigation technique.

1. Inadequate drainage.
2. Irrigation with salty water and overexploitation of groundwater.

Qualitative evaluation

In Europe, salinisation impacts around 3.8 million acres. Campania in Italy, the Ebro Valley in Spain, and also the Great Alföld in Hungary are the most afflicted, although parts in Greece, Portugal, France, Slovakia, and Austria are also affected. Salinisation has serious implications for present and future land usage. Salinisation has the following consequences: z Loss of soil fertility due to the harmful effects of excessive salt concentration.

1. Water infiltration and absorption are reduced, leading in greater run-off.
2. Transport infrastructure damage caused by shallow saline groundwater.
3. Water supply infrastructure has been damaged.
4. Decreased biodiversity.
5. Land value deterioration

There is a scarcity of data on the economic consequences of salinisation. The overall expenses of salinisation have to be calculated using information from three countries: Spain, Hungary, and Bulgaria. The yearly expenditures indicated above were calculated using the following assumptions:

Z The extrapolation for on-site expenditures primarily addresses the effects of decreasing agricultural output. In the lack of European figures, the implications for these three nations were assessed using an Australian research, which projected off-site expenditures to be around €10/ha. The overall salinisation expenses for these three nations are projected to be between €158 and 321 million yr-1. Extrapolation at the EU level was deemed impossible. Any up scaling of data would be deceptive in the absence of more comprehensive information at the proper geographical scale.

Qualitative evaluation

Landslides are natural occurrences that can be enhanced or aggravated by human activity or, conversely, by a lack of human activity. Landslides are more common in locations with highly erodible soils, clayey subsoil, steep slopes, strong and plentiful precipitation, and land abandonment, such as the Alpine and Mediterranean regions. Landslides are mostly caused by human-induced factors such as: z Rupture of topography, such as building activities; and z Land use changes, such as deforestation and land abandonment.

Land Degradation Trends

There is insufficient information on the whole impacted region in the EU. More than half of Italy's area has been classed as having a high or very high hydrogeological risk, affecting 60% of the population, or 34 million people. More than 15% of the terrain and 26% of the people are at extremely high danger (EEA 2000, MOE 2000), and the International Disaster Database has documented eight large landslides. Landslides are becoming more dangerous as a result of population expansion, summer and winter tourism, intensive land use, and climate change. The Université Catholique de Louvain's International Disaster Database lists twelve examples of large landslides for the EU25, two-thirds of which are from Italy. The quantifiable evidence on the occurrence and costs of landslides derived from that database.

Landslides' costs cannot be extrapolated in the same way that other soil risks, which occur more frequently and are more widespread, can. On the other hand, shows a broad range of expenses for landslides ranging from €11 to 600 million per event (based on information on economic repercussions for only three incidents). Italy is the country with the most information. According to the Italian Civil Protection Authority, landslides cost the Italian economy between €1 and €2 billion per year and have resulted in 5,939 deaths during the previous century. Up to 3,300 km of roads and railroads in a single Italian area (Emilia Romagna) are exposed to active landslides There is evidence that the off-site social costs form the majority of the total damage The provided data did not allow for extrapolation to the EU level. More than two centuries of industry have left their mark on soil quality. Europe has a problem with historical soil pollution caused by the usage and presence of hazardous compounds in various manufacturing processes. Nevertheless, soil pollution is still occurring as a result of poor procedures and accidents.

The following are the primary human-induced driving forces of contamination: z Industrial installations. Z Mining installations.

1. Improperly managed illegal trash dumps and landfill sites.
2. Chemical storage.

Chemical spills, both accidental and intentional. Atmospheric depositions of toxic compounds. Military installations. Deliberate introduction of dangerous substances into the soil. Soil pollution is a widespread issue throughout Europe. Most experts agree that the data supplied is insufficient for analysing some characteristics, such as total surface area poisoned per contaminant class, proportion of people exposed to contamination, environmental harm resulting from polluted sites, and so on. This is due in part to the fact that the evidence obtained by each Member State is not comparable.

According to available information, the scope of polluted sites across Europe is immense, and progress in tackling the issue is quite uneven, with some Member States far ahead in identifying the size and localization of the problem, while others are still in the early stages. The repercussions of soil pollution are wide-ranging and far-reaching. Once polluted, soil functions may be compromised, as well as human and ecological health and food quality. The repercussions can be felt where the pollution occurs, but they are typically felt in a vast surrounding region, which includes agricultural land, homes, and/or natural reserves. Contamination costs vary according to the kind of pollutant, the spatial extent and severity of the pollution, and the natural properties of the contaminant.

Due to a lack of up-to-date and comparable data, quantifying land degradation in Europe is challenging. Yet, considerable land degradation processes may be recognised throughout Europe based on existing data. These processes are largely caused by humans and can be worsened by extreme weather occurrences. The major driving reason is unsustainable economic development, which is quickly eroding Europe's non-renewable soil resources. Successful soil protection policies need to be founded on a thorough examination of the costs of inaction as well as the possible economic advantages of improved soil conservation techniques in Europe. The existing data on the principal soil risks allow for the following conclusions:

Z Erosion: the EEA estimates that water erosion affects 115 million ha, or 12% of Europe's total land area, while wind erosion affects 42 million ha, with 2% seriously affected.

Decrease in organic matter: Soil organic matter (SOM) is important in the carbon cycle of the soil. Indeed, soil is both a greenhouse gas emitter and a large carbon storage, storing 1,500 gt of organic and inorganic carbon. In Europe, around 45% of soils have a low or extremely low organic matter concentration (0-2% organic carbon), whereas the other 45% have a medium amount (2-6% organic carbon). The problem is most severe in the southern nations, although it also appears in sections of France, the United Kingdom, Germany, and Sweden.

Compaction: estimates of soil compaction danger differ. According to some studies, 36% of European subsoils are very or extremely susceptible to compaction. According to some statistics, 32% of soils are very sensitive and 18% are moderately impacted.

Salinisation is the buildup of soluble salts in soils, primarily sodium, magnesium, and calcium. It impacts around 3.8 million hectares in Europe. Campania in Italy, the Ebro Valley in Spain, and the Great Alföld in Hungary are the most afflicted, although parts in Greece, Portugal, France, Slovakia, and Austria are also affected.

Landslides are more common in locations with highly erodible soils, clayey subsoil, steep slopes, strong and plentiful precipitation, and land abandonment, such as the Alpine and Mediterranean regions. There is no statistics on the overall area impacted in the EU as of yet, but this problem might be caused by population increase, summer and winter tourism, intensive land use, and climate change.

Contamination: After more than two centuries of industrialization, Europe has a problem with soil contamination caused by the usage and presence of hazardous compounds in various manufacturing processes. It is predicted that 3.5 million sites are potentially polluted, with 0.5 million already contaminated and in need of cleanup.

Sealing: In Member States, the sealed area, or the amount of the soil surface covered with an impermeable substance, accounts for around 9% of the total area. From 1990 and 2000, the EU15's sealed area expanded by 6%, and demand for both Chapter 5: Trends in Land Degradation in Europe 103 new buildings are being built as a result of growing urban sprawl and transportation infrastructure.

Biodiversity decline: soil biodiversity includes not only the diversity of genes, species, ecosystems, and functions, but also the ecosystem's metabolic ability. All of the degradation processes indicated above have an impact on soil biodiversity, and all of the driving forces mentioned apply (equally) to soil biodiversity loss. Though difficult to determine, various studies show that soil deterioration has large yearly costs to society in the range of:

There is no way to measure the reduction of biodiversity

There are presently no estimates of the costs of compaction, soil sealing, or biodiversity loss. On the basis of existing statistics, the overall costs of soil degradation for erosion, organic matter loss, salinisation, landslides, and pollution might be up to €38 billion per year for the EU25. Due to a lack of appropriate quantitative and qualitative evidence, our estimations must be broad.

These expenses do not include the damage to soil's biological services, which could not be quantified. As a result, the true costs of soil deterioration are likely to surpass the figures provided above. Nevertheless, it should be noted that these costs of soil degradation do not account for the impact of requirements set in January 2005 under the Common Agricultural Policy cross-compliance plan, nor the impact of additional measures subsequently implemented by Member States. Yet, because soil changes are so gradual, the present estimate of the scope of the problem is most likely an acceptable reference. The majority of the costs are borne by society in the form of infrastructure damage caused by sediment runoff, increased health-care needs for people affected by contamination, treatment of contaminated water, disposal of sediments, depreciation of land surrounding contaminated sites, increased food safety controls, and costs related to soil ecosystem functions. The European Union's Soil Thematic Strategy paves the way for adequate measures to reverse the negative trends in soil and land degradation in Europe, and it will also have a significant impact on a global scale by promoting similar actions within the framework of internationally binding agreements related to land degradation, such as the UNCCD, UNFCCC, and CBD.

CHAPTER 5

FUNDAMENTALS OF DESERTIFICATION

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The United Nations Convention to Fight Desertification (UNCCD) currently defines desertification as "land deterioration in arid, semi-arid, and dry sub-humid areas caused by a variety of causes, including climate fluctuations and human activities" (UNCCD 1999). Furthermore, the UNCCD defines land degradation as "the reduction or loss, in arid, semi-arid, and dry subhumid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest, and woodlands as a result of land uses or a process or combination of processes, including processes arising from human activities and habitation patterns, such as: I soil erosion caused by wind and/or water; according to the UNCCD, land degradation directly affects approximately 250 million people. Furthermore, one billion people in over a hundred nations are at risk. Many of the world's poorest, most disadvantaged, and politically powerless citizens are among them.

When one considers that only about 11% of the global land surface can be considered prime or Class I land, and this must feed the 6.3 billion people today and the 8.2 billion expected in 2020 (Reich et al. 2001), the issue of land degradation for global food security and environmental quality assumes significant importance. As a result, land degradation may remain a top priority on the world agenda in the twenty-first century. To minimise land degradation, sustainable land management strategies are required. Land degradation is often caused by unsustainable land management practises or human growth over time. Climate resources and the danger of climate-related or created natural catastrophes in a region must be recognised in order to appropriately assess sustainable land management techniques. Only by combining climatic resources with possible management or development practises can the potential for land degradation be estimated and relevant mitigating technologies addressed. Climate information must be used in establishing sustainable practises since climatic variance is one of the key elements contributing to or even causing climate change.

Land Degradation Extent and Rate

Worldwide evaluation of land degradation is a difficult endeavour that requires a variety of methodologies, including expert judgement, remote sensing, and modelling. Due of varying definitions and language, accessible figures on the amount and rate of land degradation vary greatly. Moreover, most data focus on the dangers of deterioration or desertification (as a result of climatic variables and land use) rather than the actual (current) status of the land. Various land degradation mechanisms also muddle existing statistics on soil and/or land degradation. Land degradation processes include water and wind erosion, chemical degradation (acidification, salinization, fertility depletion, and decrease in cation retention capacity), physical degradation (crusting, compaction, hard-setting, and so on), and biological degradation (reduction in total and biomass carbon and decline in land biodiversity). The latter includes significant worries about surface water eutrophication, ground water pollution, and trace gas emissions (CO2, CH4, N2O, NOx) from terrestrial/aquatic ecosystems to the atmosphere. The essential feature that influences all degradative processes is soil structure. Land quality, as impacted by its fundamental features of climate, topography and landscape position, climax vegetation, and biodiversity, particularly soil biodiversity, are factors that govern the kind of degradative processes.

In an evaluation of population levels in the world's dry lands, the United Nations Development Programme's (UNDP) Office to Fight Desertification and Drought (UNSO) found that dry lands cover 54 million square kilometres, or 40% of the land area (UNSO 1997). Around 29.7% of this area is classified as desert, 44.3% as semi-arid, and 26% as dry sub-humid. Asia (34.4%) and Africa (24.1%) have the greatest proportion of dry areas, followed by the Americas (24%), Australia (15%), and Europe (2.5%). According to Figure 6.1, the regions of the world vulnerable to land degradation cover approximately 33% of the global land surface. At the worldwide level, it is estimated that the yearly income lost in desertification-affected areas amounts to around US$ 42 billion per year.

Africa's semi-arid to weakly aridic areas are particularly vulnerable due to their fragile soils, relatively high population density, and often low-input agriculture (Lal 1988). Over 25% of Asian countries' land is susceptible. Long-term food productivity is jeopardised by soil degradation, which is currently severe enough to diminish yields on around 16% of agricultural land, mostly farmland in Africa, Central America, and African pastures. Land degradation is more severe in Sub-Saharan Africa. Cropping land productivity losses in Sub-Saharan Africa are estimated to be in the range of 0.5-1% each year, implying a productivity loss of at least 20% over the previous 40 years (Scherr 1999).

Africa is particularly vulnerable since land degradation processes affect around 46% of the continent when one considers that around 43% of the continent is classified as harsh deserts, the significance of this enormous region becomes clear (the desert margins represent the areas with very high vulnerability.) Just around 11% of the land mass is humid and, as a result, is not subject to desertification processes. There are approximately 2.5 million km2 of land classified as low risk, 3.6 million km2 as moderate risk, 4.6 million km2 as high risk, and 2.9 million km2 as extremely high danger. The region with the highest proclivity is found in the desert borders and accounts for around 5% of the landmass. This area is home to around 22 million people (2.9% of the total population). The low, moderate, and high vulnerability classifications account for 14, 16, and 11% of the total, affecting around 485 million people. Land degradation is also a major issue in Australia, with over 68% of land considered to be degraded According to the UNCCD, the consequences of land degradation include food production undermining, famines, increased social costs, a decrease in the quantity and quality of fresh water supplies, increased poverty and political instability, a decrease in land's resilience to natural climate variability, and decreased soil productivity**.**

Land degradation is the result of two interconnected and complex systems: the natural environment and the human social system (Barrow 1994). Natural factors, such as periodic pressures from intense and persistent meteorological events, and human use and abuse of sensitive and fragile dry land ecosystems, can operate in concert, resulting in feedback mechanisms that are not completely understood. The interactions between the two systems determine whether resource management strategies succeed or fail. Land degradation is caused by a variety of factors, including biophysical, socioeconomic (e.g., land tenure, marketing, institutional support, income, and human health), and political (e.g., incentives, political stability).

High population density is not always associated with land degradation. Rather, the level of deterioration is determined by what a people does to the land. Individuals may be a valuable asset in correcting a downward trend. Indeed, mitigation of land degradation can only occur if land users have control and are committed to maintaining resource quality. They must, however, be healthy and politically and economically motivated to care for such land, as subsistence agriculture, poverty, and illiteracy may all be major contributors to land and environmental deterioration. There are several, often perplexing, reasons why property investors allow their land to decline. Many of the causes are connected to social ideas of land and the values that people place on it. In certain nations, the lack of land tenure and the associated lack of stewardship is a major impediment to appropriate land care. Since degradation is a long and unnoticeable process, many individuals are unaware that their land is deteriorating.

Land degradation can be accelerated by the loss of vegetation due to feedback between the ground surface and the atmosphere. This happens when there is less vegetation, which lowers evaporation and increases the amount of radiation reflected back to the atmosphere (albedo), limiting cloud formation. Large-scale tests using computer models of the general circulation with artificially high albedo over dry terrain have shown that considerable increases in subtropical albedo might diminish rainfall.

Climatic consequences of land degradation

The land surface plays an essential role in the climatic system. The connection between the ground surface and the atmosphere involves a number of processes and feedbacks, all of which might change at the same time. It has been repeatedly stated that changes in plant type can alter the parameters of regional air circulation and largescale external moisture fluxes. Changes in surface energy budgets caused by land surface change can have a significant impact on the Earth's climate. Surface evapotranspiration and sensible heat flow are connected to the dynamic structure of the low-level atmosphere after deforestation. These variations in fluxes within the atmospheric column may have an impact on regional, and even worldwide, atmospheric circulation. Changes in forest cover in the Amazon basin, for example, influence moisture transfer to the atmosphere, regional convection, and hence regional rainfall. Recent research indicates that changes in forest cover have far-reaching impacts outside the Amazon basin.

Landscape fragmentation can have an impact on convective flow regimes and rainfall patterns both locally and regionally. El Nio occurrences and land surface modification simulations with climate models indicate that in equatorial locations with frequent towering thunderstorms, unsettling areas hundreds of kilometres on a side may have global consequences. Garrett used a numerical simulation model to study the interactions between convective clouds, the convective boundary layer, and a forested surface and discovered that surface parameters such as soil moisture, forest coverage, transpiration, and surface roughness can influence the formation of convective clouds and rainfall by influencing boundary-layer growth.

An atmospheric general circulation model with realistic land-surface properties was used to investigate the climatic effect of doubling the extent of the Earth's deserts and most regions, and it revealed a significant correlation between decreases in evapotranspiration and resulting precipitation. Northern Africa experiences a severe year-round drought, but southern Africa has a slightly lesser year-round drought. Surface temperature increased in several locations, notably the Sahel, due to decreasing soil moisture and latent-heat flow.

Changes in land use and land cover affect carbon fluxes and GHG emissions, which directly modify atmospheric composition and radiative forcing qualities. They also affect land-surface properties and, by extension, climate processes. Measurements made during the HAPEX-Sahel study revealed that converting fallow savannah to arable crops such as millet might reduce evaporation. Changes in land use and land cover are major factors in shaping ecosystem and landscape susceptibility to environmental change. Carbon (C) emissions have been estimated to be 27030 gigatonnes (Gt) owing to fossil fuel burning and 1365 Gt due to land use change and soil cultivation since the industrial revolution. Emissions from land use change include those described in Chapter 6: Climate and Land Degradation: An Overview 111 deforestation, biomass burning, conversion of natural to agricultural ecosystems, draining of wetlands, and soil cultivation are all examples of land degradation. Soil organic C (SOC) pool depletion has supplied 7812 Gt of C to the atmosphere, with around one-third ascribed to soil degradation and increased erosion and two-thirds attributed to mineralization (Lal 2004). Land degradation exacerbates CO2-induced climate change by releasing CO2 from removed and dead vegetation and reducing the carbon storage capacity of degraded land.

Climatic Factors Contributing to Land Degradation

Climate has a significant impact on the kind, biomass, and variety of dry land plants. Precipitation and temperature influence the potential spread of terrestrial plants and are important elements in the formation and evolution of soil. Precipitation also has an impact on plant production, which limits the geographical and temporal distribution of grazing and favours a nomadic lifestyle. With decreased yearly rainfall, vegetation cover becomes thinner and less continuous. Dry land plants and animals adapt physiologically, anatomically, and behaviorally to moisture and temperature challenges caused by huge diurnal and seasonal changes in temperature, rainfall, and soil moisture.

Williams and Balling (1996) offered an excellent account of the characteristics of dryland soils and vegetation, as well as the effects of climate on the soils and plants. The arid regions' normally high temperatures and minimal precipitation contribute to low organic matter production and quick oxidation. Low organic matter causes poor aggregation and aggregate stability, which increases the possibility for wind and water erosion. Wind and water erosion, for example, is widespread in many places of Africa. Excluding the existing deserts, which cover around 46% of the landmass, approximately 25% of the land is prone to water erosion and approximately 22% to wind erosion.

Raindrop impact creates structural crusts/seals, which can reduce infiltration, increase runoff, and cause overland flow and erosion. Changes in rainfall volume and intensity, as well as variations in wind speed, are likely to affect the severity, frequency, and extent of erosion. Land management will continue to be the primary determinant of soil organic matter (SOM) content and erosion susceptibility over the next few decades, but changes in vegetation cover due to short-term weather and near-term climate changes are likely to affect SOM dynamics and erosion, particularly in semi-arid regions. According to the assessment of land resource stresses and desertification in Africa conducted by the Natural Resources Conservation Service of the United States Department of Agriculture (Reich et al. 2001) using information from Africa's soil and climate resources, climatic stresses account for 62.5% of all stresses on land degradation in Africa. High soil temperature, seasonal surplus water, short duration low temperatures, seasonal moisture stress, and protracted moisture stress are examples of climatic stressors.

The most significant climatic element in defining areas at risk of land degradation and desertification is rainfall. Rainfall is essential for the growth and dispersion of plant life, yet its unpredictability and extremes can cause soil erosion and land degradation if left uncontrolled for an extended length of time, land deterioration can lead to desertification. The impact of human activity on plant distribution through land management techniques and seemingly innocuous rainfall events might render land more sensitive to deterioration. When the threat of climate change is included, these vulnerabilities become much more apparent. Rainfall and temperature are the most important elements in establishing the global climate and, as a result, the distribution of plant kinds. Because water is one of the key inputs to photosynthesis, there is a significant link between rainfall and biomass. To identify desert (arid) or semi-arid locations, climatologists employ an "aridity index" (the ratio of yearly precipitation to potential evaporation) (UNEP 1992; Williams and Balling 1986; Gringof and Mersha 2006). Drylands develop because yearly water loss (evaporation) surpasses annual rainfall, resulting in a continuous water deficit in these areas. Deserts are the epitome of a climate in which yearly evaporation greatly surpasses annual rainfall. In circumstances where the yearly rainfall exceeds a certain threshold.

When the shortages are not so severe, some plant life can establish itself, generally in the shape of grasslands or steppes. These dry plains on the outskirts of the world's deserts, however, are the most vulnerable to desertification, the most extreme manifestation of land degradation. The Pampas of South America, the Great Russia Steppes, the Great Plains of North America, the Savannas of Southern Africa, and the Sahel area of Northern Africa are examples of these regions. Water deficits can be bigger in some years than others due to natural climatic fluctuation, but there can also be a several-year period of water deficit or long-term drought. Land degradation may be seen during this time period in the Dust Bowl years of the 1930s in the Great Plains or the almost two-decade-long drought in the Sahel in the 1970s and 1980s. This era of drought in the Sahel is responsible for the present concern about desertification.

Soil erosion data has been gathered and studied by soil scientists, agronomists, geologists, hydrologists, and engineers for over a century. Scientists have constructed a basic soil erosion relationship based on these research, which incorporates the primary soil erosion components. The Universal Soil Loss Equation (USLE) was established in the mid-1960s to help agricultural researchers comprehend soil erosion. It was updated and renamed the Revised Universal Soil Loss Equation (RUSLE) in the mid-1980s to incorporate the large amount of information that had accumulated since the original and to address land use applications other than agriculture such as soil loss from mined lands, construction sites, and reclaimed lands. The RUSLE is based on soil erosion theory as well as over 10,000 plot-years of data from natural rainfall plots and various rainfall simulations.

where A symbolises soil loss per year (t/ha/year), R the rainfall-runoff erosivity factor, K the soil erodibility factor, L the slope length, S the slope steepness, C the cover management factor, and P the supporting practises factor. These elements demonstrate how numerous climatic, geologic, and human factors interact, and how sensible land management approaches may reduce soil erosion and, ideally, land degradation.

Excessive or insufficient rainfall can cause soil erosion, which can lead to land deterioration. Yet, of the many elements that induce soil erosion, soil experts believe rainfall to be the most essential. Zachar presents an overview of soil erosion caused by rainfall, including the power of raindrops, surface and subsurface flow, and river floods. The kinetic energy released by rain hitting the soil surface is significant, and it has the potential to dislodge soil particles. At this micro-scale, erosion can also be triggered by readily dissoluble soil material that has been rendered water soluble by weak acids in rainfall. The breaking apart and splashing of soil particles generated by raindrops is simply the initial step of the process, which is followed by soil particle washing away and additional erosion induced by running water. Yet, without surface drainage, rainfall causes relatively little soil erosion.

As soil particles get loosened, they are vulnerable to discharge. In general, the higher the intensity of the rainfall, the more soil accessible in runoff water. When there is a lengthy period of light rain, the majority of the soil dislodgement occurs in the aquatic environment, and the soil particles are generally fine. The bigger the soil particles transported away, the greater the intensity of the downpour and subsequent surface runoff. The permeability of the soil, which indirectly effects the overall quantity of soil loss and the pattern of erosion on slopes, is a crucial component that causes soil erosion by rainfall. One unintended consequence of runoff is the transportation of agricultural pesticides and their leaching into groundwater. Rainfall intensity is the most significant element influencing rain-induced soil erosion. Dry land precipitation is naturally changeable in terms of amount and intensity, as is runoff. Since dry land soils produce impermeable crusts under the pressure of heavy thunderstorms and in the absence of extensive plant cover or litter, surface runoff is frequently higher in dry lands than in more humid places. Soil transfer may be an order of magnitude larger per unit momentum of falling raindrops in these instances than when the soil surface is highly vegetated. The less plant cover there is, the more exposed the topsoil is to dislodgement and removal via raindrop impact and surface runoff. Moreover, the timing of rainfall can have an important effect in soil erosion and land degradation.

An inconsistent start to the rainy season, combined with excessive rain, will have a bigger impact since seasonal vegetation will not be there to intercept the rainwater or support the soil through its root structure.

Scientists are working hard to include all of these characteristics into models that can forecast soil erosion. The Water Erosion Prediction Project (WEPP) model is a process-based, distributed parameter, continuous simulation, erosion prediction model for use on personal computers that may be deployed at the field size to simulate hillslope erosion or more complicated watershed scale erosion (USDA 2006). It imitates the natural processes that contribute to soil erosion. Every day, it updates the soil and crop conditions that effect soil erosion. When it rains, the plant and soil properties are utilised to predict whether or not surface runoff would occur. Climate and weather (rainfall, temperature, solar radiation, wind, freeze-thaw, snow accumulation and melting), irrigation (stationary sprinkler, furrow), hydrology (infiltration, depressional storage, runoff), water balance (evapotranspiration, percolation, drainage), soils (types and properties), crop growth (cropland, rangeland, forestland), residue management and decomposition, tillage are all conceptual components of the WEPP model.

The effect of different types of precipitation on soil erosion is particularly noteworthy (Zachar 1982). Hail has a significant impact on the soil surface because its kinetic energy is many times that of rain, resulting in substantially more soil surface destruction and material being swept away. Additionally, if hailstorms are accompanied by heavy rain, as some thunderstorms are, enormous amounts of soil can be eroded, particularly on agricultural area, before crops can stabilise the soil surface. Snow thaw erosion occurs when the earth freezes throughout the winter season and the freezing process dislodges the soil, causing fine soil particles to be discharged as runoff during the spring thaw. This type of erosion can frequently result in larger erosion losses than rain. Furthermore, when the soil freezes, the infiltration rate is considerably slowed, allowing rather strong soil erosion to occur even when the amount of snow melt is minor. In this case, the erosive processes can be accelerated by a combination of heavy rain and a quick inflow of warm air. Leeward mountainous places are vulnerable to this because they are often drier, have less vegetation, and are subject to katabatic winds (rapidly descending air from a mountain range warms very quickly).

Floods

Dryland Rivers have extremely variable flows and discharge, and the volume of suspended sediments is particularly susceptible to changes in rainfall and plant cover in the basins. The loss of vegetation in the headwaters of Dryland Rivers can increase sediment load and result in a drastic change in the river's character, resulting in a less stable, more seasonal river with a rapidly moving sequence of channels. Rainfall, on the other hand, can cause land degradation in other climates, especially sub-humid ones. Heavy rainfall events caused by thunderstorms, hurricanes, and typhoons, as well as mid-latitude low-pressure systems, can generate a tremendous volume of water in a short period of time throughout local areas. This surplus of water overwhelms the local watershed, resulting in river flooding. Of fact, this is a natural occurrence that has been occurring for millions of years.

Climate Change and Land Degradation: An Overview The world has been shaped for 117 years. River flooding happens in all climates, although the problem is most severe in dryland areas. Flood forecasting is a complex procedure that must take many different aspects into consideration at the same time, depending on the kind and nature of the phenomena that causes flooding. For example, broad flash floods are sometimes initiated by heavy rain falling in one region inside a greater area of lighter rain, creating a perplexing situation that makes forecasting where the biggest flood will occur difficult. Flooding produced by heavy rain or storm surges that might wash inland as part of a tropical cyclone can also be a difficult task, as projections must incorporate where they will land, the stage of their evolution, and the physical properties of the shore.

Under the auspices of the WMO, National Hydrological Services (NHSs) and National Meteorological Services (NMSs) conduct flood forecasting based on quantitative precipitation forecasts (QPFs), which have become more accurate in recent years, particularly for light and moderate amounts of precipitation, though high amounts and rare events remain difficult to predict. As a result, establishing forecasting systems that integrate meteorological predictions with those for water-related occurrences is becoming more feasible by the day, opening the way for a genuinely integrated approach.

Forecasting must also be a collaborative and diverse endeavour. Because of the numerous challenges and complexities of floods, flood managers must collaborate with meteorologists, hydrologists, municipal planners, and civil defence authorities to use available integrated models. Identifying the socioeconomic repercussions of floods would need a detailed examination of building and other activity in and around river systems. Up-to-date and reliable information is required via all available channels, including surface observation, remote sensing, satellite technologies, and computer models.

Flood risk assessment and management have existed for decades, but there has lately been a trend towards Integrated Flood Management. Integration is the defining feature of Integrated Flood Management, and it manifests itself in several ways: an appropriate mix of strategies, points of intervention, types of interventions (i.e. structural or non-structural), short or long-term, and a participatory and transparent approach to decision making - particularly in terms of institutional integration and how decisions are made and implemented within the given institutional structure. To ensure consistency in planning, land use planning and water management must be merged in a single synthesised plan by coordination between land management and water management bodies. The justification for this integration is that land use affects both water quantity and quality. The three basic components of river basin management are inextricably linked: water quantity, water quality, and erosion and deposition processes.

Drought is a natural hazard caused by a lack of precipitation, resulting in a water deficit for certain activities or populations. It is caused by a decrease in precipitation for a lengthy period of time, generally a season or more, and is sometimes linked with other meteorological variables, such as high temperatures, high winds, and low relative humidity, which can exacerbate the severity of the event. The 2002-03 El Nio-related Australian drought (Coughlan et al. 2003), for example, lasted from March 2002 to January 2003 and was undoubtedly one of, if not the, worst short-term droughts in Australia's recorded meteorological history (Nicholls 2004). Examination of rainfall data for this 11-month period revealed that 90% of the country got rainfall below the long-term median, with 56% getting rainfall in the lowest 10% (i.e., decile1) of totals recorded (Australia-wide rainfall records commenced in 1900). During the 2002-03 drought, Australia witnessed extensive bushfires, severe dust storms, and agricultural consequences, resulting in a 1% decline in Australia's GDP (Watkins 2005). For much of Australia, the first five months of 2005 were abnormally dry, prompting many to identify this time as a genuinely extraordinary drought.

Long-term droughts in certain desert places have started or aggravated land degradation. Droughts have been widespread in Africa, with severe events in 1965-1966, 1972-1974, 1981-1984, 1986-1987, 1991-1992, and 1994-1995. The aggregate impact of drought on African economy may be significant: 8-9% of GDP in Zimbabwe and Zambia in 1992, and 4-6% of GDP in Nigeria and Niger in 1984. The Sahel has undergone the most significant and prolonged reduction in rainfall documented anywhere in the globe during the time of instrumental observations during the last 25 years. The Sahelian droughts of the early 1970s were particularly severe, dubbed "the quintessence of a catastrophic environmental calamity," and their long-term consequences are just now becoming obvious.

Anomalies in sea surface temperature (SST), which are frequently associated with the El Nio Southern Oscillation (ENSO) or the North Atlantic Oscillation (NAO), contribute to rainfall variability in the Sahel. Droughts in West Africa are associated with warm sea surface temperatures in the tropical south Atlantic. A study of oceanographic and meteorological data from 1901 to 1985 revealed that prolonged wet and dry episodes in the Sahel were associated with opposing patterns of SST anomalies on a near-global scale (Sivakumar 2006). ENSO-cycle SST anomalies and vegetative output in Africa were found to be associated from 1982 to 1990. Warmer eastern equatorial Pacific waters during ENSO periods were associated with 1,000 mm yr-1 rainfall over some African locations.

According to a coupled surface-atmosphere model, whether human forces or changes in SST caused the 1968-1973 Sahel drought, persistent loss of Sahel savannah vegetation would allow drought conditions to endure. Drought has the effect of increasing ground and near-surface air temperatures while decreasing surface radia-tion by lowering soil moisture and hence evaporation and cloud cover and increasing surface albedo as plant cover is eliminated. Balance and worsening the local surface-atmosphere system's radiation deficit. This results in increasing atmospheric sinking and, as a result, even less precipitation. Early warning systems can mitigate the effects of drought by giving timely information about its onset Surface perception at its most basic

National Meteorological Services stations are one link in the network, providing critical benchmark data and time series for enhanced climate and hydrologic system monitoring. Monitoring particular indicators, such as stream flow or soil moisture, can aid in the creation of drought index values, which are often single figures that are significantly more useful for decision-making than raw data. Drought strategies should include three key elements: monitoring and early warning, risk assessment, and mitigation and response (Wilhite and Svoboda 2000). Since droughts have a gradual beginning, monitoring and early warning systems are the core of an efficient drought mitigation strategy.

To activate mitigation and emergency response initiatives, a strategy must rely on accurate and timely evaluations. Several WMO programmes monitor drought-related extreme climatic occurrences, while four monitoring centres - two in Africa, one in China, and the Global Information and Early Warning System - give weather warnings and one and three-month climate summaries. The Southern Africa Development Community (SADC), among other African early warning systems, analyses agricultural and food status in the area and gives alerts during times of oncoming catastrophe. These networks can serve as the foundation for drought contingency planning, or coordinated measures for coping with drought when it occurs.

Evaporation, temperature, and solar radiation

The sun is the only source of energy for the Earth, yet our planet only intercepts a minuscule fraction of this energy (less than a tenth of one percent) to generate energy for the many biological (photosynthesis) and geophysical (weather and climate) processes on which life depends. According to fundamental physics laws, the earth system must release the same quantity of radiation that it absorbs. As a result, the intricate flow of energy required to meet this demand is the foundation of our weather and climate. Solar radiation is closely associated with cloudiness, and when there are few or no clouds in most dryland regions, solar radiation may be fairly powerful. In reality, locations like the Sahara desert have some of the highest known amounts of solar radiation. The primary contributor to air temperature is solar heating of the ground surface.

Temperature, together with rainfall, is the most important element in influencing climate, and hence the spread of plant and soil formation. Several variables influence soil formation, including the source material (rock), geography, climate, biological activity, and time. Weathering and leaching processes in soils vary depending on temperature and rainfall. Temperature fluctuations, both seasonal and daily, can have an impact on soil moisture, biological activity, chemical reaction rates, and other factors.

The varieties of vegetation are discussed in Chapter 6: Climate and Land Degradation - an Overview. The nitrogen and carbon cycles are important chemical interactions in soil. Surface soil temperatures in the tropics can surpass 55o C, and this strong heat adds to the cracking of highly clay soils, exposing not only the soil surface but also the soil subsurface to water or wind erosion. These high temperatures will, of course, increase soil evaporation and diminish available soil moisture for plant development. The movement of boulders and stones from various depths to the surface of the soil in temperate dry regions can have a direct influence on the composition of the soil. The freeze-thaw cycle is one element that degrades rock formations at high elevations, generating fractures and fissures that can lead to landslides and rock avalanches.

The conversion of water from a liquid or solid state to vapour and subsequent passage into the atmosphere is known as evaporation. Evaporation requires a vapour pressure difference between the evaporating surface and the atmosphere, as well as an energy source. The major source of energy is solar radiation, which determines the broad boundaries of evaporation. The tropics have high solar radiation levels that are affected by cloud cover, resulting in a high evaporative demand of the atmosphere. Significant energy may be advected from neighbouring dry areas over irrigated zones in arid and semi-arid environments. According to Rosenberg et al. (1983), various investigations have demonstrated the "oasis effect," which is the movement of energy over an evaporating surface that can generate considerable evaporative losses in a short amount of time.

Climatic conditions increase the evaporative demand of the atmosphere, but the actual evaporation will be determined by the type of the evaporating surfaces as well as water supply. In degraded soil, the albedo and surface roughness of the land surface impact evaporative demand, with the latter affecting turbulence. In dry and semi-arid locations, excessive evaporation surpasses precipitation, resulting in salt deposition on the soil surface. Soils with a natric horizon spread quickly, and the low moisture levels result in restricted biological activity.

Wind

Wind erosion causes moderate to severe land degradation throughout the world's arid plains, and there is evidence that the frequency of sand storms/dust storms is rising. Wind erosion is predicted to cause moderate to severe land degradation in the world's arid and semi-arid zones, affecting 24% of cultivated land and 41% of grazing area (Rozanov 1990). The total yearly generation of dust through deflation of soils and sediments was estimated to be between 61 and 366 million tonnes worldwide (Middleton 1986). Wind erosion causes major desert soil loss worldwide. The top limit for worldwide estimates of desert dust long-range transport is around 1 x 1016 g year -1. It is estimated that more than 100 million tonnes of dust are carried westward over the Atlantic each year from Africa. The quantity of dust emitted by the Sahel zone has been estimated to be about or over 270 million tonnes per year, which correlates with

Sand and dust storms are dangerous weather patterns that pose significant agricultural and environmental issues in many places of the world. Because of the sand and dust storms, there is a significant on-site and off-site expense. They can move like an overwhelming tide, and strong winds carry drifting sands to bury farmlands, blow out top soil, denude steppe, harm animals, attack human settlements, lower temperatures, fill irrigation canals and road ditches with sediments, cover railroads and roads, cause household dust damage, affect the quality of water in rivers and streams, affect air quality, pollute the atmosphere, and destroy mining and communication facilities. They hasten the process of land degradation, causing major contamination and massive devastation to the nature and living environment. Wind erosion causes atmospheric dust loading, which has an impact on human health and environmental air quality.

Wind erosion-induced agricultural damage includes direct crop damage from sandblasting and decreased photosynthetic activity, burying of seedlings under sand deposits, and loss of topsoil. The final step is particularly concerning because it has the potential to have a long-term impact on the soil resource base and hence crop yield by eliminating the layer of soil that is naturally rich in nutrients and organic matter.Wind erosion on light sandy soils can cause significant land degradation, and sand deposits on young seedlings can interfere with crop establishment. Wind erosion occurs anywhere meteorological events interact with soil and land management through their impacts on soil structure, tilth, and plant cover. Wind erosion is frequently a major problem in areas where lengthy dry periods with strong seasonal winds occur on a regular basis, the vegetative cover of the land does not adequately protect the soil, and the soil surface is disturbed owing to poor management methods.

A unique dry and hot wind known locally as Harmattan blows around the southern edge of the Sahara Desert. Under a high atmospheric pressure system, these NE or E winds are common in the winter. When the wind force of Harmattan exceeds a certain threshold, sand and dust particles are blasted away from the land surface and transported hundreds of kilometres to the Atlantic Ocean.

The convective sand-dust storm that happens in the Northwest area of India in the season preceding the monsoon is known as Andhi. In Africa and Arabic nations, it is known as Haboob. It is known as "phantom" or "demon" in various parts of the world. In general, two indications are used to classify the intensity of sand-dust storms: wind velocity and visibility. For example, sand-dust storms in India's northwest are divided into three categories. When the wind velocity is at force 6 (Beaufort) and visibility is between 500 and 1,000 metres, a weak sand-dust storm forms. The subsequent intense sand-dust storm will begin when the wind velocity reaches force 8 and visibility ranges from 200 to 500 metres. When the wind speed is 9 and the visibility is 200 metres, strong sanddust storms will occur.

A sand-dust storm is characterised similarly to the above in China. The main distinction is that the category of powerful sand-dust storms is divided into two levels, strong sand-dust storms and serious-strong sand-dust storms. A violent sand-dust storm occurs when the wind velocity is 50 metres per second (m/s) and the visibility is 200 metres. When the wind speed is 25 m/s and visibility is 0-50 m, the sandstorm is classified as a serious sand-dust storm (some places call it a Black whirlwind or Black Devil).

Four definitions of the dust phenomenon are the same as those used by the Australian Bureau of Meteorology, which adheres to the World Meteorological Organization's global standards (WMO). The following SYNOP current weather codes are included:

Dust storms (SYNOP WW code: 09) are caused by turbulent winds that raise enormous amounts of dust into the air, decreasing visibility to less than 1,000 metres. Mannava Robert Stefanski and V.K. SivakumarThe extremely fine component of soil-derived dust has considerable radiative forcing effects. Dust particles are hypothesised to have a direct radiative impact on climate by reflecting and absorbing solar energy, as well as indirectly through affecting the optical characteristics and lifespan of clouds. Dust particles, depending on their characteristics and location in the atmosphere, can reflect sunlight back into space and produce cooling in two ways. They directly reflect sunlight back into space, lowering the quantity of energy reaching the surface. They operate as condensation nuclei indirectly, resulting in cloud formation (Pease et al. 1998). Clouds operate as an "atmospheric blanket," keeping long-wave radiation released by the earth within the atmosphere. As a result, dust storms have local, national, and worldwide consequences for global warming. Climate change can alter the location and strength of dust sources.

Wildfires, Deforestation, and Atmospheric Emissions

Uncontrolled wildfires occur across the world's vegetation zones. Fires are estimated to affect 1015 million hectares (m ha) of boreal and temperate forest and other lands each year, 2040 million hectares (m ha) of tropical rain forests due to forest conversion activities and escaped agricultural fires, and up to 500 million hectares (m ha) of tropical and subtropical savannas, woodlands, and open forests. The amount of the soil organic carbon pool is approximately two to three times bigger than that deposited in living organisms in all terrestrial ecosystems on Earth. In this scenario, one of the many biological and environmental effects of fires is that they are a large producer of greenhouse gases that contribute to global warming. Worldwide, biomass burning, including wildfires, is estimated to create 40% of carbon dioxide, 32% of carbon monoxide, 20% of particulates, and 50% of extremely carcinogenic poly-aromatic hydrocarbons produced by all sources. Existing methods for measuring global emissions are restricted by a lack of reliable data on area burnt and fuel available for combustion.

Fire emissions are enormous and contribute considerably to total world emissions of trace gases and particles to the atmosphere from all sources. Natural emissions are responsible for a large fraction of the components that influence tropospheric oxidant concentrations, such as non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), and nitric oxide (NO). The total NMVOC flow is predicted to be about 841012 g of carbon (Tg C), with isoprene accounting for 35%, 19 additional terpenoid chemicals accounting for 25%, and 17 non-terpenoid compounds accounting for 40%. The effect of fire on soil characteristics (soil-water content, compaction, temperature, infiltration ability, soil properties, particularly organic matter, pH, exchangeable Ca, Mg, K, Na, and extractable P) in a semi-arid southern African rangeland was quantified over two growing seasons (2000/01-2001/02) following an accidental fire (Snyman 2003). The loss of basal cover due to fire (head fires) exposed the soil to more natural elements, resulting in greater soil temperatures and compaction, resulting in lower soil-water content and decreased soil infiltrability.

CHAPTER 6

LAND DEGRADATION AND CLIMATE CHANGE

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Human actions, particularly the combustion of fossil fuels and changes in land cover, alter the concentration of air elements or the qualities of the Earth's surface that absorb or deflect radiant radiation. Increases in the quantities of greenhouse gases (GHGs) and aerosols, in particular, have been firmly linked as contributors to the climatic changes witnessed throughout the twentieth century and are projected to contribute to additional changes in climate in the twenty-first century and beyond. Temperatures, precipitation patterns, sea level, severe events, and other characteristics of climate on which the natural environment and human systems rely are anticipated to change as a result of these changes in atmospheric composition.

Ecosystems are under pressure from a variety of factors, including land-use change, resource demands, and population shifts, according to the IPCC (2003); their range and pattern of distribution are changing, and landscapes are becoming more fragmented. Climate change is an additional stressor that has the potential to alter or harm ecosystems and the numerous products and services they supply. Temperature rise will have an effect on soil characteristics and processes such as organic matter decomposition, leaching, and soil water regimes. The negative impacts of rising air temperatures on agricultural production are anticipated to be exacerbated by soil erosion and degradation. Climate change may enhance erosion in some areas due to increasing rainfall and wind speed.

Because of feedbacks between land degradation and precipitation, CO2-induced climate change and land degradation are inexorably intertwined. Climate change may increase land degradation by altering temperature, rainfall, solar radiation, and wind patterns through time and space. Many climate models predict that future global warming would diminish soil moisture across vast swaths of semiarid grassland in North America and Asia.

This climatic change is expected to accelerate the deterioration of semiarid regions that has already occurred. For the coming decade, rapidly rising human populations will be the reason. According to Emmanuel, climatic change caused by a doubling of atmospheric CO_2 level will result in a 17% increase in the global area of desert land. Since water resources and climate are intricately intertwined, the likelihood of global climate change has major consequences for water resources and regional development. Climate change, particularly increases in climatic variability caused by droughts and flooding, will make resolving these issues more difficult. The poor, who have the most limited access to water resources, will continue to bear the brunt of the consequences.

Changes in precipitation and increased evaporation might have a significant influence on some lakes and reservoirs.

Lakes and reservoirs respond to climatic variability in the paleoclimate of Africa and in the current climate through severe variations in storage, leading to full drying out in many cases. Additionally, these studies reveal that under the current climatic regime, some big lakes and wetlands have a delicate balance between inflow and outflow, with evaporative increases of 40%, for example, resulting in significantly decreased outflow. The frequency of episodic transfer by wind and water from dry places is also expected to increase as global climate changes. Wind erosion would be exacerbated by lower soil moisture and sparser plant cover. Reduced organic matter inputs and increased SOM oxidation may impair soil's long-term water-retention ability, aggravating desertification. Also, increasing wind erosion increases wind-borne mineral dust, which may enhance radiation absorption in the atmosphere.

Carbon sequestration for climate change mitigation and land degradation

The pool of soil organic carbon (SOC) at one metre deep ranges from 30 tonnes ha-1 in dry climates to 800 tonnes ha-1 in cold climate organic soils (Lal 2007). Conversion of natural to agricultural ecosystems depletes the SOC pool by up to 60% in temperate soils and up to 75% or more in tropical farmed soils. When the production of carbon (C) exceeds the intake and soil degradation is severe, the depletion is compounded. Carbon sequestration entails putting atmospheric CO2 into long-lived pools and safely storing it so that it is not reemitted soon. Soil C sequestration entails growing SOC and soil inorganic carbon reserves through wise land use and management approaches. Mulch farming, conservation tillage, agroforestry and diversified cropping systems, cover crops, and integrated nutrient management, including the use of manure, compost, biosolids, enhanced grazing, and forest management are some of these approaches.

The theoretical carbon sink capacity of managed ecosystems roughly equals the projected total past C loss of 55 to 78 gigatonnes (Gt). Offsetting fossil-fuel emissions with realistic SOC potential brings several ecological and socioeconomic benefits. A tonne of soil carbon added to degrade farmland soils may boost crop output by 20 to 40 kg ha-1 for wheat, 10 to 20 kg ha-1 for maize, and 0.5 to 1 kg ha-1 for cowpeas, thus improving global food security (Lal 2007).

WMO's Role in Studying the Relationships between Climate and Land Degradation

The World Meteorological Organization (WMO) is the United Nations specialised body in charge of meteorology and operational hydrology. WMO assists its 188 Member States and Territories' National Meteorological and Hydrological Services (NMHSs) in their distinct roles of observing and studying weather and climate, as well as delivering meteorological and associated services in support of national needs. These requirements are particularly relevant to the protection of life and property, the preservation of the environment, and the promotion of long-term development. WMO scientific programmes have been critical in advancing understanding of the climate system. The systematic observations made using established procedures have offered global data for study, research, and modelling of the atmosphere and its changing weather patterns. Through the Global Observing System of the World Weather Watch Programme, WMO manages a global network for the collecting and exchange of observational data. The system consists of around 10,000 land stations, 1,000 upper-air stations, 7,000 ships, 3,000 aeroplanes that provide over 150 000 observations every day, and a constellation of 16 meteorological, environmental, operational, and research satellites. The World Meteorological Organization also coordinates a network of three World Meteorological Centres, Regional Specialized Meteorological Centres, and 187 National Meteorological Centres. Specialized observational programmes, such as those for chemical constituents of the atmosphere and ocean characteristics and circulations, have improved understanding of interactions between the domains of the climate system the atmosphere, the oceans, the land surface, and the cryosphere, as well as climate variability and change.

WMO specifically contributes to understanding the interactions between climate and land degradation through dedicated observations of the climate system; advances in climate science and prediction; and promotion of capacity building in the application of meteorological and hydrological data and information in drought preparedness and management. In this context, the World Meteorological Organization (WMO) will continue to address the issue of land degradation through its Agricultural Meteorology Programme, Hydrology and Water Resources Programme, and other scientific and technical programmes by:

1. Wind erosion capability Index value 0-20 mph wind erosion capability Zero or insignificant
2. Blowing dust is raised to moderate heights above the ground by winds, decreasing vision at eye level, but not below 1,000 m.
3. Dust haze is caused by suspended dust particles that have been elevated from the ground by a dust storm before to the time of observation.
4. Dust swirls (or dust devils) are spinning columns of dust that move with the wind and are typically less than 30 m high (but can reach 300 m or more). They often disappear after a short distance.

Wind erosivity is the primary element governing the overall pattern of wind erosion. It has been characterised as "the wind attribute that determines its capacity to entrain and transport bare, dry soil in fine tilth" (Painter 1978). It may be calculated using daily or hourly wind speed recordings above a threshold related to the slowest speed at which soil particles are entrained (Skidmore and Woodruff 1968). Chepil and Woodruff (1963) created a wind erosion capacity (C) index defined as: where V = wind speed at standard observation levels (10 m), m s-1; P = precipitation (mm); and Ep = potential evapotranspiration (mm).

When soil movement is sustained, the amount of dirt that the wind can transport changes with the cube of the velocity. Wind erosion accelerates rapidly over a certain wind speed, according to models. In the corn belt of the United States, a 20% increase in mean wind speed increases the frequency with which the threshold is surpassed, and consequently the frequency of erosion occurrences. Many attempts have been made to include all of these wind erosion components into a computer model. The Wind Erosion Prediction System (WEPS) is one such endeavour. It is a process-based, daily time-step model that forecasts soil erosion by simulating the underlying mechanisms influencing wind erosion (Wagner 1996).When wind speeds surpass the erosion threshold, the WEPS model can compute soil movement, estimate plant damage, and anticipate PM-10 emissions.

WMO is committed to working with UNCCD Parties to improve weather, climate, and water resource observing systems in order to meet the needs of the Convention, and to assisting developing countries in strengthening their participation in the collection and use of these observations in order to meet their commitments to the Convention. In this regard, it is important to examine the Decisions of the Conference of Parties of the United Nations Framework Convention on Climate Change (UNFCCC) that address the issue of climate observing systems, as well as the regional workshop programme developed and implemented by the Global Climate Observing System (GCOS) Secretariat, which is co-sponsored by WMO.

Increasing the effectiveness of early warning systems

Early warning systems are a crucial and important alert tool in the fight against land degradation. Because meteorological and hydrological hazards are linked to climate variability, regular assessments and authoritative statements on the interpretation and applicability of observational data are required for the study of climate variability as well as the implementation of a climate alert system to allow NMHSs to issue early warnings on pending significant climate anomalies. Climate-related crisis warnings are becoming possible weeks to seasons in advance. The World Meteorological Organization's World Climate Programme will continue to issue routine statements on the state of El Nio or La Nia, which, through the NMHSs, can alert governments to ensure preparedness against the impacts of El Nio-related anomalies, which can trigger a variety of disasters. WMO participated actively in the work of the ad hoc Panel on early warning systems formed by the UNCCD's Committee on Science and Technology (CST). The Panel's recommendations include conducting a critical analysis of the performance of early warning, monitoring, and assessment systems; improving methods and approaches to drought prediction and desertification monitoring; and developing mechanisms to facilitate information exchange, with a focus on national and subregional networks. WMO's new major programme on Natural Disaster Prevention and Mitigation will serve as a focal point for the organization's efforts to consolidate early warning activities and to launch new initiatives in this area in partnership with other organisations.

Improving Climate Prediction Capability

Climate prediction skills are being improved through the World Climate Research Programme's Climate Variability (CLIVAR) programme (WCRP). El Nio and its related repercussions may now be predicted with good accuracy up to a few seasons in advance. In connection with this, WMO is expanding the execution of the WMO Climate Information and Prediction Services (CLIPS) project, which aims to encourage the use of climate information and prediction services, capacity building, multidisciplinary research, and the development of new applications. Drought consensus long-term predictions made at many Regional Climate Outlook Fora hosted in various regions of the world with active cooperation from WMO give valuable early warning information to national authorities.

Vulnerability assessment and risk analysis

It is critical to evaluate the adequacy of early warnings by analysing vulnerability at the local, national, and regional levels. The linking of weather, climate, and disaster databases to the many types of meteorological or hydrological catastrophes is a useful tool for assessing those various risks. In this regard, a pilot project linking climate and flood disaster databases is currently underway in Chile, with WMO support via the World Climate Programme, as part of the activities of the Inter-Agency Task Force for Disaster Reduction (IATF) Working Groups on Climate and Disasters and Risk Vulnerability and Impact Assessment. This is a crucial tool for policymakers and communities to use when communicating about risk. Via data rescue and climate database management programmes, WMO will continue to help in the development and administration of key climate datasets.

Risk management application implementation

In order to battle droughts and mitigate floods, risk management measures must be used. In this context, hazard mapping, appropriate agroclimatic zoning, and partnership formation are critical tools for land use and preparation planning. Numerous expert teams created by the World Meteorological Organization's Commission for Agricultural Meteorology (CAgM) are critically analysing these concerns and delivering advisory recommendations to users. In the framework of integrated water resources management, WMO's Hydrology and Water Resources Programme is executing the Associated Programme for Flood Management (APFM) in partnership with the Global Water Partnership. In order to give direction on the creation of support systems for sustainable land management and agroclimatic zoning, several relevant projects are being created in various regions of the world in Chapter 6: Climate and Land Degradation - an Overview 131.

Contributing actively to the execution of the UN system's International Disaster Reduction Strategy (ISDR). It should be noted that society's ability to cope with and adapt to climate change will be heavily dependent on its ability to assess how and where weather and climate patterns are likely to change, predict continuous fluctuations in risk and vulnerability to communities, and develop adaptive strategies that will increase the community's resilience when the next potential disaster strikes. WMO is in charge of the ISDR Working Group on Climate and Disasters.

Drought-related programmes are being used to help the Parties and regional organisations develop their capacities. The capabilities of Parties and regional institutions with drought-related programmes will be strengthened, and collaboration with other institutions in drought- and desertification-prone regions will be encouraged, with a focus on Africa, Asia, Latin America and the Caribbean, and the northern Mediterranean region, all of which are mentioned in the Convention's Regional Annexes.

The AGRHYMET Centre and the African Centre of Meteorological Applications for Development, both in Niamey, Niger, the IGAD Climate Prediction and Applications Centre in Nairobi, Kenya, and the SADC Drought Monitoring Centre in Gaborone, Botswana are examples of similar institutes in Africa. WMO organised Roving Seminars on the Application of Climatic Data for Desertification Control, Drought Preparedness, and Sustainable Agriculture Management in Beijing, China in May 2001 and Antigua and Barbuda in April 2004 to improve capacity building in the development of National Action Plans within the framework of the Convention.

Prospects for the Future

The UNCCD definition of land degradation emphasises the importance of climatic factors in land degradation, but there is no concerted global effort to systematically monitor the impacts of different climatic factors on land degradation in different regions and for different classes of land degradation. As a result, monitoring the linkages between climate and land degradation is critical. It is also necessary to define the sources and sinks of dryland carbon, aerosols, and trace gases in order to better understand these interactions. This may be accomplished successfully using regional climate monitoring networks, according to Mannava V.K. Sivakumar and Robert Stefanski. These networks might also assist to improve the use of seasonal climate predictions for more effective dryland management.

Several locations have significant gaps in the fundamental meteorological network and observational facilities, some of which are in areas with severe land degradation concerns. The most critical and geographically extensive problem is a lack of rainfall intensity data. WMO is assisting in the development of early warning systems by arranging the development of appropriate equipment and statistical processing. Furthermore, WMO is coordinating efforts among its Members to conduct additional research into using data from meteorological satellites to supplement knowledge of meteorological conditions influencing land degradation, particularly over areas that are insufficiently covered by ground-level observations. WMO is glad to be a part of the effort to better understand the role of climate in land degradation and to collaborate with different national, regional, and international agencies, as well as civil society, in combatting and stopping land degradation.

As a result of anthropogenic climate change, the frequency of occurrence of climatic extremes is predicted to shift during the next century, with increases in the frequency of heat waves and heavy precipitation events and decreases in the frequency of frost days. Changes in the frequency of severe events would affect land degradation processes such as floods and mass movements, soil erosion by both water and wind, and soil salinisation. Analyses of climatic extremes in the second half of the twentieth century demonstrate major worldwide trends in both temperature and rainfall. Future projected changes in climate extremes until the end of the twenty-first century exhibit significant geographical and temporal variability, with the uncertainties surrounding future precipitation increases being larger than those around future temperature changes.

Climate extremes include both extreme weather with durations ranging from minutes to days (the synoptic timeframe) and extreme climatic events with durations ranging from months in the case of wet/stormy weather to years in the case of drought. In all circumstances, seasonal to inter-annual oscillations in large scale climatic variations such as El Nio/Southern Oscillation (ENSO) and North Atlantic Oscillation (NAO) can influence the frequency of severe occurrences. It is still difficult to distinguish between natural climatic variability and human climate change. In contrast to the record of catastrophic climate events, the implications of such occurrences on land degradation have received less attention. Case studies of specific occurrences and their societal implications are somewhat common, but instances that integrate daily meteorological records spanning decades with individual event impact records are quite unusual. In this study, we look at the difficulties in keeping track of exceptional occurrences and their consequences. Case studies are used to investigate the effects of particular events on land degradation and their temporal and geographical variability at the decadal scale. Future changes in the frequency of severe events are studied using an ensemble of general circulation models and regional climate models.

CHAPTER 7

CLIMATE EXTREMES CLASSIFICATION

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Extreme occurrences are differentiated by their magnitude (for example, exceptionally high or low temperatures, significant rainfall, or dry spells). A length of record is required for all sorts of severe events before a frequency distribution can be derived; for example, we need to know whether the frequency of extreme rainfall occurrences per decade has changed. A minimum of 40 years of continuous record is necessary for daily rainfall or temperature data. The length and consistency of the record are essential because they allow for official claims, such as the UK Meteorological Office's recent conclusion that fall 2006 was the hottest in a 347-year record. Temperature extremes can alter when the mean and variance of the probability distribution of daily temperatures shift. Small increases in mean daily precipitation values can result in proportionally much larger increases in the probability of extreme daily rainfall events, and one way to represent such changes is in terms of the magnitude and frequency (or recurrence interval) of these daily rainfall events, as schematically. Several indicators of extreme climatic events have been proposed.

The necessity for suitable lengths of record poses issues since it is obvious from the global distribution of meteorological stations that some areas, notably in Africa, the Middle East, South Asia, and South America, have scant station coverage. Several stations may no longer be operational in other areas. Rainfall in dry, semi-arid, and sub-humid locations may be very variable both geographically and temporally, hence using regional average of station data to discover exceptional rainfall events may result in these occurrences remaining unreported. Extreme occurrences having a gradual beginning, such as heatwaves or droughts, are more difficult to identify. Some analyses employ basic measurements such as the maximum number of consecutive dry days or the persistent exceedance of specific temperatures, although definitions are particularly challenging in the case of drought (Figure 7.1). Drought can be classified as'meteorological,' 'agricultural,' or 'hydrological.'

Number of days below a specific rainfall threshold, soil moisture deficits, or surface and groundwater storage levels, respectively (Pielke et al. 2005). Empirically based indicators can identify the relative severity of a specific drought event and assess the geographical and temporal variability of drought (Edwards and McKee 1997). The Palmer Drought Severity Index (PDSI) (Palmer 1965) is extensively used, although it requires temperature and precipitation data, as well as empirical connections, to establish a climatic weighting factor. The Standardised Precipitation Index (SPI), which is based on the analysis of monthly rainfall series, is simpler to calculate and provides results at multiple timescales relevant to soil moisture, streamflow, and groundwater conditions. Another advantage of the SPI technique is that it allows for the identification of both exceptionally wet and extremely dry periods.

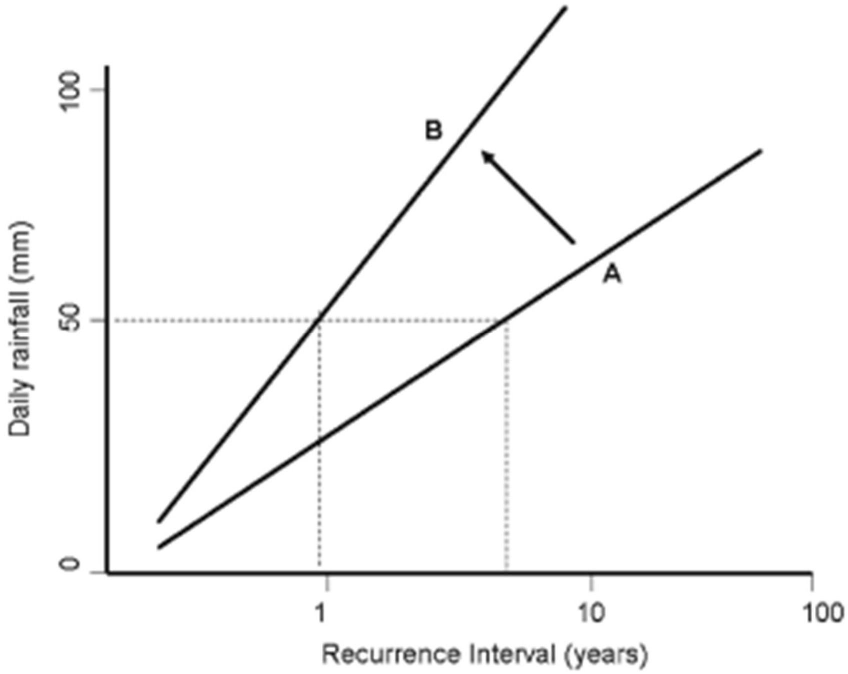

Figure 7.1 represents the climate extremes.

Extreme wind speeds, rainfall, and storm surges can all be expected from tropical storms and extratropical depressions. Storminess is defined as the number of days with Beaufort Wind Scale/World Meteorological Organization wind speeds ranging from 7 (13.9-17.1 ms-1) to 11 (> 28.4 ms-1) for any of four 6-hourly data sets for that day (Qian and Saunders 2003). Tropical storms are classified as Category 1 to 5 on the Saffir-Simpson scale, with Category 1 storms having sustained wind speeds of 74-95 miles per hour-1 (33.1-42.5 ms-1) and/or storm surges of 4-5 ft (1.2-1.6m) above normal, and Category 5 storms having sustained wind speeds of > 155 miles per hour-1 (>69.2 ms-1) and/or storm surges of > 18 ft.

While there are numerous approaches for categorising severe occurrences, not all extreme events have the same influence on land degradation. Certain land degradation processes, such as landsliding or gully incision, may require the crossing of a specific threshold, and subsequent occurrences of lesser scale may reactivate the landslide or develop/enlarge the gully. Nevertheless, some land degradation processes, notably land use changes and land management practises, may be accelerated by human activity, whilst others may be efficiently alleviated by anthropogenic intervention techniques. Floods and accompanying channel erosion and deposition, mass movements, including landslides and debris flows, and the more diffuse processes of soil erosion by water and wind, as well as salinisation, are the key land degradation processes addressed here.

The integration of meteorological data with land degradation processes presents considerable monitoring issues. Extensive records are needed to estimate return durations and probability of recurrence. The effects of severe events on land degradation may not be captured as thoroughly as meteorological data. Extreme events' consequences are often only reported if they have an influence on human populations and society, and occurrences impacting metropolitan regions or infrastructure are also more likely to be recorded than those affecting rural areas. The effects of severe events can also be determined independently by monitoring other natural environment variables such as water and sediment flows. While studies of the consequences of single severe events, such as rainfall events in southeast Spain and Italy, are reasonably widespread, longer term data sets are uncommon. Statistics on gully growth, for example, are usually dependent on the study of repeated remotely sensed pictures, but the real timings of gully system incision and development are unknown and hence unrelated to climatic data.

Certain parts of the northern Mediterranean are subject to floods, mass movements, and soil erosion caused by water due to a combination of climate, relative relief, and geology (Luino 2005). We will look at two case studies from southern Italy that have daily meteorological and land degradation information. Throughout the period 1951-2000, a total of 46 exceptional rainfall events, defined as 5-day intervals with rainfall exceeding 10% of the mean annual value, were identified for southeast Basilicata in southern Italy. Documentation records of landslides and floods were examined, and the antecedent rainfall for each incident was documented in terms of P2 (rainfall 2 days before the event) and P30 (rainfall 30 days prior to the event). The scale of the landslides ranges from single landslides blocking small roads to many incidents affecting multiple villages at the same time. P30 > 50mm was documented for all incidents, P30 > 100mm for 73% of landslides and floods, and P2 >100mm for 16%. Nevertheless, only 59% of the identified severe rainfall events had a land surface impact (Clarke and Rendell 2006a). This disparity might be attributed to a lack of reporting or to the good impacts of mitigation throughout the time period investigated.

An analogous research in the Campania region of southern Italy's Benevento area employed a Rainfall Hazard Index (RHI) technique to designate exceptional occurrences (Diodato 2004). In this example, the 24-hour antecedent rainfall was employed, and 33 rainfall events were recognised as surpassing a crucial threshold between 1926 and 2002, while data on hydro geomorphological events (floods, mass movements, and soil erosion) were obtained separately over the same time period. 22 (67%) of the 33 severe rainfall occurrences studied were related with floods, landslides, and/or erosion events, whereas 11 (33%) were not (Diodato 2004). Like with the Basilicata research, there is a mismatch between exceptional occurrences and their consequences in the long-term daily record. Regardless of how the severe occurrences were classified, not every meteorologically defined extreme rainfall event resulted in a reported land surface impact in the case of either of these records.

Using the 50-year or 76-year records for Basilicata and the Benevento area, respectively, the frequency of extreme rainfall events changes with time, reflecting changes in winter cyclonic activity in the Mediterranean caused by decadal scale variability in the North Atlantic Oscillation. Positive NAO index values are associated with extreme low pressure over Iceland and high pressure over the Azores, which drive Atlantic storm tracks over northwest Europe (Britain and Scandinavia). Negative NAO index values represent reduced Icelandic low pressure and Azores high pressure, as Atlantic storm tracks migrate through the Iberian Peninsula and into the

Mediterranean. Trigo et al. examined the inventory of 19 landslides that occurred in the Lisbon region of Portugal between 1958 and 2001 in terms of both antecedent rainfall and NAO state. All of the landslide incidents were connected with negative NAO index values.

Flooding, gully incision, and development in the Southwest United States We now look at the issues that might occur when both meteorological records and documentation records of land degradation are fragmented. Throughout the late nineteenth and early twentieth centuries, gully incision and development occurred along the courses of ephemeral rivers and streams in the southwest United States (Cooke and Reeves 1976).

Secular temperature changes, anthropogenically induced changes in vegetation with the advent of cattle ranching, and the construction of dams, flood control channels within drainage networks have all contributed to taneous gully incision (Cooke and Reeves 1976; Bull 1997). Flood-related gully incision and channel erosion have been linked to increases in winter precipitation during El Nio circulation patterns. One issue with linking precipitation and land degradation episodes is that the date of many gully entrenchment occurrences in Arizona and New Mexico is unknown. Cooke and Reeves, for example, date the incision of gullies in the Aravaipa valley from 1886 to 1914. Only in a few cases can gully incision be linked to a specific year or month. Additional data for severe floods within the Gila River watershed are available (Dobyns 1981).

Although the 'big floods' of 1868, 1891, and 1905 all occurred during El Nio occurrences (Dobyns 1981), it is obvious that the link between rainfall-driven flood events and El Nio/La Nia conditions is complicated. Ely reached a similar conclusion for an analysis of v10 yr floods in Arizona and southern Utah from 1900 to 1995, particularly with respect to summer floods, which are generally the result of convective thunderstorms and show little or no relationship with a 5 yr running mean of the ENSO Index. Over a considerably longer timeline, thorough analyses of alluvial deposits in various valleys in the southwest United States demonstrate a sequence of gully incision and aggradation stages spanning the previous 11,500 years (Bull 1997; Waters and Haynes 2001). While recent gully incision may be associated with abiotic factors, the longer term record supports a climate-driven explanation.

Soil deterioration is on the rise worldwide, particularly in tropical areas. Droughts occur every four years in Tanzania, affecting 3.63 million people, according to historical statistics. The most often impacted locations are Dodoma, Singida, and sections of Pwani, Shinyanga, Mwanza, and Mara. Annual rainfall ranges from 200 to 600 mm in certain areas. Droughts have been recurrent in regions of Tanzania in recent years. The most severe were in 1983-1984 and 1993-1994. Droughts forced hydroelectric power rationing, resulting in negative economic growth.

East Matari Street

Land use activities have exacerbated soil deterioration in marginal zones to the point that it can no longer sustain living populations. The human population and cattle in these marginal areas have risen dramatically in recent decades, necessitating additional food and fibre production as well as other resources. Demands on soils, vegetation, and climate are currently far beyond their potential to give in many locations. The land's carrying capacity has been exceeded. Drought has forced pastoralists into farming in certain regions, resulting in significant disputes. Rainfall in Tanzania is an important component in farmers' and pastoralists' capacity to produce commodities for human use.

Because rainfed agriculture is the mainstay of the economy, prolonged droughts have terrible consequences for the country's socioeconomic growth. Floods happened 15 times between 1980 and 2000, killing 54 persons and impacting 800,270 people. Tanga, Mbeya, Pwani, Morogoro, Arusha, Rukwa, Iringa, Kigoma, and Lindi are among the flood-prone areas. One of the biggest causes of soil deterioration is the management of arable land by farmers and grazing land by animal owners. Land management that is more sustainable would minimise environmental constraints. Conservation tillage, or decreased or no tillage, is the key to long-term arable land management because it maintains soil resources, promotes water efficiency, and is especially important in semi-arid locations since it mitigates the impacts of droughts.

Land/soil degradation can occur as a result of natural risks or as a result of poor land use and land management methods. Flooding on steep slopes is a common natural danger, as are tornadoes, high velocity winds, heavy rainfall, intense leaching in humid locations, and drought conditions in dry parts. Soil erosion is caused by anthropogenic activities such as deforestation of sensitive areas, removal of vegetation, shifting agriculture, overgrazing, uneven fertiliser usage, non-adoption of soil conservation management measures, and over-pumping of ground water. Desertification is currently described as "land deterioration in arid, semi-arid, and dry sub-humid regions caused by a variety of causes, including climate fluctuations and human activities" by the UNCCD. According to the UNCCD, land degradation directly affects approximately 250 million people. Moreover, one billion individuals in over 100 nations are at danger. Many of the world's poorest, most disadvantaged, and politically powerless citizens are among them.

The effect of rain on soil degradation in Tanzania

The most important climatic element in defining areas at risk of land degradation and desertification is rainfall. Rainfall is essential for the growth and dispersion of plant life, yet its unpredictability and extremes can cause soil erosion and land degradation. If left uncontrolled for an extended length of time, land deterioration can lead to desertification. Land degradation can be exacerbated by the spread of plants as a result of land management activities and, ostensibly, rainfall events. When the threat of climate change is included, these vulnerabilities become much more apparent. Rainfall and temperature are the most important elements in establishing the global climate and, as a result, the distribution of plant kinds. Because water is one of the key inputs to photosynthesis, there is a significant link between rainfall and biomass. The "aridity index" (the ratio of yearly precipitation to potential evaporation) is used by climatologists to help define desert (arid) or semi-arid environments. Dry

E. Matari lands occur because yearly water loss (evaporation) exceeds annual rainfall, resulting in a continuous water deficit in these areas. Deserts are the epitome of a climate in which yearly evaporation greatly surpasses annual rainfall. In circumstances when yearly water deficits are not so severe, plant life can take hold, often in the shape of grasslands or steppes. Rainfall intensity is the most significant element influencing rain-induced soil erosion. Dryland precipitation is naturally changeable in terms of amount and intensity, as is runoff. Since dry land soils produce impermeable crusts under the pressure of heavy thunderstorms and in the absence of extensive plant cover or litter, surface runoff is frequently higher in drylands than in more humid places. Soil transfer may be an order of magnitude larger per unit momentum of falling raindrops in these instances than when the soil surface is highly vegetated. The more sparsely planted the area, the more prone the topsoil is to dispersal and loss owing to raindrop impact and surface runoff. Moreover, the timing of rainfall can have a significant impact in soil erosion and land degradation. A irregular start to the rainy season, combined with excessive rain, will have a higher impact since seasonal vegetation will not be there to intercept rainfall or anchor the soil with its root system.

The effect of different types of precipitation on soil erosion is particularly noteworthy. Hail has a significant impact on the soil surface because its kinetic energy is many times that of rain, resulting in substantially more soil surface destruction and a bigger volume of material swept away. Additionally, if hailstorms are accompanied by heavy rain, as some thunderstorms are, enormous amounts of soil can be eroded, particularly on agricultural area, before crops can stabilise the soil surface.

The most prevalent kind of human-induced soil deterioration is loss of top soil due to water erosion. It is commonly referred to as surface wash or sheet erosion. It occurs in practically every country, under a wide range of climatic, physical, and land use circumstances. While topsoil is generally rich in nutrients, a significant proportion of nutrients are lost along with the topsoil. Topsoil loss is frequently preceded by compaction and crusting, resulting in a decrease in soil infiltration capacity and rapid run-off and soil erosion.

The most prevalent manifestations of this sort of deterioration are rill and gully development. Quick gully incision, consuming important soil, is widely recognised and dramatic in many areas. Additional detrimental effects of this sort of deterioration include riverbank damage and mass movement (landslides), as well as off-site deposition of eroded material (choking of river beds; smothering of riverside crops). The destruction of above-ground vegetation and animal populations is widespread in many regions, caused by direct human intervention and exacerbated by cyclical droughts (Sahel, Southeastern Africa, and Northeastern Brazil). In general, this biotic deterioration appears to be reversible in a few years once the rains return and the ground "rests" from excessive human or animal activity.

Dryland Rivers have extremely variable flows and discharge, and the volume of suspended sediments is particularly susceptible to changes in rainfall and plant cover in the basins. Flood-prone locations in Tanzania are distinguished by a high risk of rainfall exceeding 1000 mm. This is a situation from the 1997/98 El Nio year, when floods induced by severe rainfall wiped out numerous farms with crops. The loss of vegetation in the headwaters of Dryland Rivers can increase sediment load and result in a drastic change in the river's character, transforming it into a less stable, more seasonal river with a rapidly moving sequence of channels. Nonetheless, extreme rainfall events caused by thunderstorms, hurricanes, and typhoons can cause land degradation in different climates, including sub-humid areas.

Drought is defined by agriculturalists as a lack of moisture inside the root zone for plant growth and development. Droughts, on the other hand, are causing catastrophic reductions in stream, lake, and reservoir levels, according to hydrologists. Droughts are viewed by economists as a major water scarcity that has a negative impact on the economy. Droughts, on the other hand, are viewed by meteorologists as merely a lengthy period of precipitation deficit that creates severe hydrological imbalance. According to Mutoni, the central and north-eastern areas of Tanzania are at high risk of drought. It is caused by a decrease in precipitation for a lengthy period of time, generally a season or more, and is sometimes linked with other meteorological conditions such as high temperatures, high winds, and low relative humidity, which can exacerbate the severity of the event.

Drought is a natural, recurrent aspect of climate that occurs in practically all climatic regimes, in both high and low rainfall locations. It is a passing phenomenon, as opposed to aridity, which is a permanent component of the environment and is limited to places with little rainfall. Drought is caused by a natural decrease in the amount of precipitation received over a lengthy period of time, generally a season or more. Drought is also affected by the time (i.e. major season of occurrence, delays in the commencement of the rainy season, incidence of rains in connection to primary crop growth phases), severity, and quantity of rainfall events. As a result, each drought is distinct in terms of its climatic traits and consequences Tanzania has a high probability of receiving more than 1000 mm of rain.

It is estimated that more than 100 million tonnes of dust are carried westward over the Atlantic each year from Africa. The amount of dust emitted by the Sahel zone has been estimated to be at or exceeding 270 million tonnes yr-1. Wind erosion is greatest in Tanzania in locations where there is a significant risk of drought. Wind erosion-induced agricultural damage includes direct crop damage from loss of plant tissue and decreased photosynthetic activity caused by sandblasting, burial of seedlings under sand deposits, and topsoil loss. The final step is particularly concerning because it has the potential to have a long-term impact on the soil resource base and hence crop yield by eliminating the layer of soil that is naturally rich in nutrients and organic matter. Wind erosion on light sandy soils can cause significant land degradation, and sand deposits on young seedlings can interfere with crop establishment.

Calculations based on visibility and wind speed data for 100 km-wide dust plumes centering on eight climate stations in South Australia revealed that the dust transport mass might be as high as ten million tonnes. Hence, dust entrainment. The Impact of Certain Meteorological Factors on Tanzanian Land Degradation The result of 161 dust storms is long-term soil damage that is essentially irreversible. The cost to productivity is difficult to quantify, but it is likely to be significant.

Wind erosion causes

Wind erosion occurs anywhere meteorological events interact with soil and land management through their impacts on soil structure, tilth, and plant cover. Wind erosion is frequently a severe problem in locations where lengthy dry periods with strong seasonal winds occur on a regular basis, since the vegetative cover of the land does not adequately protect the soil and the soil surface is disturbed owing to poor management methods. Wind erosivity is the primary element governing the overall pattern of wind erosion. It has been characterised as "that feature of the wind which determines its ability to entrain and move bare, dry soil in fine tilth". It may be calculated using daily or hourly wind speed recordings above a threshold related to the slowest speed at which soil particles are entrained.

Dust Storms' Climatic Consequences

The extremely fine percentage of soil-derived dust significantly influences the radiation budget. Dust particles are hypothesised to radiate and indirectly change the optical qualities and duration of clouds depending on their properties and where they are present in the atmosphere. Dust particles can reflect sunlight back into space and produce cooling in two ways. They directly reflect sunlight back into space, lowering the quantity of energy reaching the surface. When the wind velocity at the soil surface exceeds the threshold velocity necessary to displace the least stable soil particle, wind erosion occurs. The separated particle may travel a few millimetres before landing in a more secure location on the terrain. The static threshold is the wind velocity necessary to shift the least stable particle. Soil movement occurs as the wind velocity increases, and it continues if the velocity is adequate. This velocity is referred to as the dynamic threshold.

Wind erosion is the regular movement of topsoil and selective removal of tiny particles caused by wind activity. It is common, especially in dry and semi-arid areas. Wind erosion deforms the terrain far less frequently than topsoil loss. Wind activity causes unequal movement of soil material, resulting in deflation hollows and dunes. Overblowing, defined as the covering of the ground surface by wind-carried particles, is an off-site impact of the aforementioned wind erosion categories. Overblowing can occur in the same or nearby mapped units. That might have an impact. To lead to additional climate change in the twenty-first century and beyond. Temperatures, precipitation patterns, seal levels, extreme events, and other elements of climate on which the natural ecosystem and human systems rely are expected to be affected by these changes in atmospheric composition.

According to the World Meteorological Organization (2006), meteorological and hydrological dangers are connected to climatic variability. For the investigation of climate variability and the establishment of a climate alert system to allow NMHSs to issue early warnings on pending large climate anomalies, regular evaluations and authoritative comments on the interpretation and relevance of observational data are required. Climate-related crisis warnings are becoming possible weeks to seasons in advance. Human-caused global climate change may or may not have a detrimental impact on the climatic conditions of drylands, resulting in their deterioration. The current Global Circulation Models are still too crude to draw definitive findings for regions or small locations. The consequences of connecting terrestrial and ocean models, as well as the direct effect of increasing atmospheric $CO2$ on plant growth, remain unknown. In contrast to methane and nitrous oxide, a rise in atmospheric carbon dioxide concentration has a direct beneficial influence on plant development via the "CO2-fertilization" and "CO2-antitranspiration" phenomena. Therefore, even a minor rise in the surface temperature of open seas due to global warming will result in a significant acceleration of the global hydrological cycle. This suggests higher rainfall in many areas, which means more transpiration-cum-growth of plants, or more run-off can be utilised on-site or downstream for extra irrigation if well stored. These elements focus on the potentially good features of human-induced climate change in agricultural and rural development, while also addressing the possible negative implications. Among the latter are the possible increases in the frequency and intensity of extreme weather events (droughts, floods, and storms) as the hydrological cycle intensifies. According to Hyera and Matari (1996), climate change would cause temperature increases of 2-3 degrees.

Rainwater collides with the ground near the soil surface. Rainfall is distributed over a number of pedohydrological components. Green water is rainwater that has been held in the soil and is now available to plants. Land degradation reduces infiltration, water retention capacity, and transpiration while increasing runoff and soil evaporation. Green Water Use Efficiency (GWUE; the ratio of transpiration to precipitation) is reduced as a result of several agrophysical processes. Estimating the consequences of land degradation on 'computing available soil moisture' is given special emphasis in order to comprehend what farmers experience as drought. Rain that falls on the land may be absorbed by plants, flow off the ground surface, or penetrate into the soil, all of which are reflected in the rainwater balance. Infiltrating water may be held in the root zone or drain below the root zone to groundwater and stream base flow, providing what is nowadays called 'blue water'.

The infiltration water balance reflects these processes. The maximum quantity of water stored in the root zone that may be used by the plant 168 Leo Stroosnijder growth is an essential soil property because it impacts plant survival during a dry spell. Water held in the root zone may be lost to the atmosphere via evaporation from the soil surface, or it may be taken up by plants and lost as transpiration. The soil water balance reflects this. The GWUE in Sub-Saharan Africa's drylands varies between 5-15%, which is quite low. It may reach 20% in East Africa, while in equivalent climes in the United States, it may exceed 50%.

Land degradation mitigation strategies are drawn from the rainfall balance. After a series of results, it is advised that we enhance our understanding of land degradation by increasing the availability of rainfall data at the combination of soil, water, and natural flora and fauna in a landscape, above and below the soil surface, is referred to as land. Land degradation is defined as a decrease in the amount of land that generates items helpful for local lifestyles (Scoones and Toulmin 1999), or, in more contemporary terms, a decrease in 'ecosystem services' (MEA 2005). The complexities of the concepts 'land' and 'land degradation,' as well as their scale characteristics, result in several meanings.

Desertification is a kind of land degradation that occurs in the arid, semi-arid, and dry sub-humid environments that are particularly prone to land degradation. Former UN Secretary-General Kofi Annan has described desertification as one of the world's most dangerous environmental degradation processes. According to the climate change scenario, droughts, flash floods, dust storms, starvation, migration, and forest fires connected with desertification are sure to grow, resulting in human well-being loss and substantial socioeconomic consequences. The fact that long-term food output is endangered by land degradation is significant and concerning, as it has a significant influence on global food security.

According to the United Nations Convention to Combat Desertification (UNCCD 1997), soil degradation directly affects approximately 250 million people. Furthermore, one billion people in over a hundred nations are at risk. Many of these individuals are among the worlds poorest and most marginalised, with little political clout. Land degradation will be examined in this study primarily in regard to Sub-Saharan Africa. In a discussion of land degradation, four spatial-temporal scales should be distinguished: regional, watershed, field, and point scales. At each scale, different proxies for land degradation can be used. There are several direct and indirect relationships between land and rainfall: rainfall impacts vegetation (productivity, cover, and biodiversity), soil water status, and soil properties. It is also vital to research rainfall at different scales in order to relate land degradation at multiple scales to rainfall.

Farmers frequently refer to soil deterioration as 'drought'. Their definition of drought is the occurrence of dry periods. Some recent studies, however, have shown no indication of a rise in the length and/or frequency of dry spells. When farmers talk about 'drought,' they must be referring to the quantity of water that may be stored in the root zone soil profile (Green Water) and how this Green Water is used. They are referring to the Green Water Usage Efficiency (GWUE), which is the percentage of rain that is utilised for plant transpiration. The GWUE in dryland systems in Sub-Saharan Africa varies between 5-15%, which is quite low in comparison to similar agro-climatic zones throughout the world. Land degradation (of which soil erosion is the primary cause) degrades soil physical features, affecting a variety of pedo-hydrological processes: it reduces infiltration, waterholding capacity, and plant transpiration while increasing runoff and soil evaporation (Stroosnijder 2003). Section 9 is dedicated to this topic. 4. Recognizing the relationship between production and rainfall balance explains the term "desertification" and gives strategies for drought mitigation at the farm level. The purpose of GWUE optimization is to maximise the productive flow of water as plant transpiration while minimising non-productive water flows such as soil evaporation, runoff, and percolation beyond the root zone. Section 9.5 elaborates on the principles of land degradation mitigation derived from the rainfall balance. Ultimately, conclusions and recommendations are made.

All current definitions of land degradation pertain to a decrease in land productivity This means that a loss in land productivity is one of the possible proxies for land degradation Soil degradation, as a component of land degradation, includes erosion and a deterioration in soil quality, including chemical changes from leaching or salinisation, physical changes from compaction or blistering, and biological changes from the loss of soil organic matter or microorganisms. It is useful to differentiate between on-site and off-site erosion while discussing erosion. Lately, a new definition based on the notion of ecosystem services has been proposed (MEA 2005). Additionally, many have accepted Warren's (2002) view that land degradation is contextual and cannot be assessed apart from its geographical, chronological, economic, environmental, and cultural context.

As a result, there are now too many definitions of land degradation. In reality, it is debatable whether changes in land or land attributes caused by purposeful changes in land use, such as economic growth, may be referred to as land degradation. Because people have changed the land from the dawn of time, it may be easier to separate such modifications from undesirable alterations in ecosystem services.

The amount, severity, and economic and environmental consequences of rapid erosion are controversial (Lal 2001). Estimates of global and regional land area impacted are speculative and subject to revision. The influence of erosion on soil quality and production is also unknown, and field assessments vary depending on size and approach. Although significant progress has been achieved in modelling soil erosion, model validation remains inadequate. Several of the preceding scholars have concluded that there appears to be little evidence of widespread land degradation, yet this does not exclude out significant local degradation in Sub-Saharan Africa. It appears that when it comes to analysing land degradation, the "experts" may be overestimating it. The disparities discovered between more empirical assessments of land degradation (based on productivity indicators and land properties) and the expert assessments and models that form the basis of most land degradation studies suggest that the methodology of the studies needs to be improved in several ways, most notably in dealing with the spatial and temporal dimensions of the problems observed). Many geographical scales will be separated in an effort to clarify this debate in the literature, each with its own relevant proxies for land degradation.

Nicholson (2000) finds minimal evidence of large-scale soil denudation, rise in surface albedo, or decline in land productivity in the Sahel, however degradation has most likely happened in isolated locations. Yet, throughout the previous half-century, there has been a gradual build-up of dust in the region, which has most likely altered large-scale climate. Several studies employ the net primary production (NPP) to precipitation ratio, often known as the rain use efficiency (RUE). This may be estimated using remotely sensed data and ground-based rain readings. RUE was determined by Prince et al. (1998) to be relatively robust, with minimal fluctuation between 1882-1990 for the Sahel, implying that NPP is in sync with rainfall, rebounding quickly from drought, and not confirming worries of widespread, large-scale desertification. Their findings revealed a minor but regular rise in RUE of 172 Leo Stroosnijder.

For Burkina Faso, Mazzucato and Niemeijer (2001) investigated the relationships between agricultural production and long-term rainfall, rural population density, and animal traction index (as a proxy for technology). A stepwise regression study revealed that agricultural production per unit of farmed land was mostly related to long-term average yearly rainfall (environment) and was only marginally associated to rural population density (resource pressure) or animal traction (technology). There was no evidence that resource pressures such as rural population density or livestock density had influenced land productivity. As a consequence, the geographical study of agricultural productivity of cultivated land found no indication of soil deterioration caused by strain on soil resources.

The difficulty in establishing the degree of erosion as a proxy is one disadvantage. The literature frequently mentions four causes: considerable temporal and geographical variation in erosion, a scarcity of good erosion measurements, the difficulty of extrapolating data from small plots to larger sizes, and the translation of erosion into production and monetary units (impact). The accuracy, equipment, and manpower expenses of measurement procedures vary. The most precise (and frequently most expensive) approaches do not always get the desired result. It is a fallacy to believe that the deployment of erosion prediction technology can replace the function of measurements. Measurements are required for the development, calibration, and validation of that technology.

There appears to be less debate over the slow but steady decline of soil organic matter (SOM). Humans have taken most of the land in cultura, i.e. into cultivation, via different stages, such as shifting cultivation, fallow rotation, and permanent usage, and so the natural landscape has turned into a cultural landscape. Its fast growth (on a geological time frame) has altered the plant cover. There is less above-ground (or 'plant') organic carbon (POC) in a 'culture landscape' than in a 'natural landscape'. Because POC and SOC (soil organic carbon) are connected, when a natural environment is turned into a cultural landscape, SOC begins to decline. This slow procedure will be repeated until SOC and POC reach a new equilibrium. Agricultural production in Sub-Saharan Africa is generally conducted in a low-input agricultural system: rainfed agriculture with little or no fertilisation - at most, a small input of animal dung or compost from domestic trash. On the other hand, agricultural goods are consumed and used almost entirely presently. Farmers consume the grain, legumes, and other crops cultivated. Uncultivated 0 - 0 + - Cultivated 0 0 0 0 = no significant change, + = greater fertility in 1996 and - = lower fertility in 1996 their families, and the straw is either used for feed (during the dry season, the animals browse on the fields) or as building material for roofs, fences, and so on. Many agro-ecological systems lose 2% of their SOM reserves each year due to a lack of organic material replenishment.

Two quandaries

The preceding confronts us with two intriguing conundrums:

(1) How is it possible that soil physicists demonstrate evidence of soil deterioration at bigger sizes but not at smaller scales?

(2) How could people living off that land have survived if, despite considerable scientific data, land degradation has been happening for decades?

The first dilemma is explained by the way the natural mosaic of soil surface states is aggregated into land, catena, and the landscape. In addition to deteriorated areas, there are always less degraded areas, which are frequently under-measured in degradation studies, resulting in an inherent bias. These later sites benefit from runoff of water and nutrients, seeds, and organic detritus, resulting in so-called fertile islands. We generalise the mosaic of such spots by aggregating point information onto larger scales. As a result, at larger scales, averaging or compensation produces less and less persuasive evidence of land deterioration. This is analogous to what is previously known from scaling runoff and sediment formation (for example, the sediment delivery ratio). The runoff from a 1 m2 plot may represent 50% of the rainfall, but at the foot of a hill slope, it may be just half that amount, and at the watershed exit, it may be only one-tenth of its original value.

In other words, when one moves from the point to the watershed scale, the intensity of erosion decreases. With its pixel size much above the point scale, our remote sensing instrument does a type of automated averaging whose effects we do not completely comprehend. Consider: are they real or fake? Moreover, our models are unsuitable for collecting mosaic information with considerable variance at 1 m scales.

Mazzucato and Niemeijer provide an explanation to the second enigma, stating that underestimating the ability of local farmers has been a key cause of overestimation of land degradation. Farmers in Sub-Saharan Africa have clearly not survived by adopting a capital-intensive growth path. This implies that they have managed to adapt their land management techniques to growing population density in an environmentally friendly manner. Soil and water conservation, as well as technology intensification, involve far more than agricultural statistics suggest. Sub-Saharan farmers have a diverse set of technology at their disposal. To deal with the restricted availability of labour and external inputs, as well as the harsh climate in which they work, they have created adaptable, efficient, and effective land management practises. Also, they were able to adapt. Many Sahelian farmers' apathy to high rates of soil loss may reflect their understanding that erosion does not severely harm productivity in the short run.

CHAPTER 8

RAINFALL ANALYSIS FOR ASSESSING LAND DETERIORATION

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It is vital to examine rainfall at many scales in order to analyse land degradation at numerous scales. Rainfall may be analysed at four distinct sizes for land degradation, ranging from the'small' yearly scale to the 'big' minute scale. Each scale has a distinct application (s). Apart from scales, there are also average values and temporal and geographical fluctuations to consider. A few instances of rainfall data for each scale are shown below and analysed in relation to land degradation.

Annual scale applications: trends and probability

Annual rainfall trends are used to evaluate variations in rainfall that effect land degradation mostly through changes in plant cover. Conway et al. find from an analysis of 100 years of rainfall in Addis Abeba that there was no significant movement or trend in annual and seasonal rainfall from 1898 to 2002. The Addis Ababa rainfall record does not include well-known drought years in northern and northeastern Ethiopia, implying that the series should not be used as a proxy for inter-annual rainfall variability in these portions of the Ethiopian highlands.

Niemeijer and Mazzucato (2001) averaged the yearly rainfall of Burkina Faso's 16 main sites having a long-term record. From 1928 to 2000, the average annual rainfall at Sakarani Mission (West Usambara Mountains, Tanzania) was 1070 mm, ranging from 441 mm y-1 to 1772 mm y-1 (Vigiak, pers. com.). The median value was 1035 mm y-1, with a dry year (10% chance of not exceeding) at 760 mm y-1 and a rainy year (90% chance of exceeding) at 1420 mm y-1. Despite the significant spread across the years, a trend towards reduced total rainfall was observed over the observation period: the mean annual rainfall from 1928 to 1948 was 1270 mm, but it was 931 mm from 1980 to 2000.

Ayoub (1999) discovered a similar pattern while researching long-term rainfall in Sudan: a 30-40% decrease. Nevertheless, Aklilu Amsalu et al. (2006) analysed rainfall dynamics in the Beressa watershed, Ethiopia, from 1954 to 2003 and discovered that, contrary to farmers' beliefs, the long-term rainfall pattern has improved. Another use for yearly rainfall data is statistical analysis to determine rainfall probability, as done by Hoogmoed and Stroosnijder (1984). Annual rainfall variation may be used to determine 'normal' (50% likelihood), 'dry' (90% chance of exceedance), and 'wet' (10% probability of exceedance) years: this method is used for modelling land use scenarios.

The average year curve for 1957, 1959, 1962, and 1975 is the 'normal' year curve. These years had total rainfall in the period July-September that was closest to the 50% chance value of a 30-year series (1950–1980). The rainfall in the 'dry' years of 1966, 1972, 1973, and 1974 came closest to the 90% chance estimates, the length of the growth season if a minimum precipitation is specified each 10-day period. For example, if the lower limit is set at 40 mm 10d-1, the amount required to trigger growth when 50% runoff is taken into account), the period up to 15 September (general flowering date due to photoperiod) will be 75 days for a 'normal' year and 53 days for a 'dry' year.

If a lower limit of 20 mm 10d-1 is established, which is sufficient for growth if runoff is nil, this time will be 108 days for a 'normal' year and 93 days for a 'dry' year. It was established in that study that rainfall distribution across the growing season in the southern Sahel is such that millet planting should be achievable. Yet, because the millet growing cycle must be as short as feasible in order to yield a satisfactory grain harvest, crop growth should begin as soon as possible. Sowing is often only practicable in moist soil because dry soil is too difficult to dig. Furthermore, rainfall may be so variable that there is a significant chance that inadequate water will be retained in the soil to keep the new plants alive in the early season, necessitating field resowing. If runoff losses could be reduced or prevented, the risk of the young crop depleting soil water stores would be reduced.

The diurnal rainfall totals obtained at Sakarani Mission from September 1991 to August 2001 were analysed to characterise the rainfall event pattern of the Kwalei watershed. Rainfall occurrences were classified into three categories: less than 10 mm, between 10 and 20 mm, and greater than 20 mm. These classifications indicated the likelihood of overland flow production, which was thought to be improbable for rain events with less than 10 mm in 24 hours. Throughout the ten years of observation, 66% of occurrences were less than 10 mm in size, 22% were between 10 and 20 mm in size, and only 12% were greater than 20 mm in size. But, in terms of total rainfall volume, events less than 10 mm contributed 27%, events between 10 and 20 mm contributed 30%, and events greater than 20 mm provided 43%.

Rainfall events more than 20 mm per 24h were common around the start of the long rainy season, in March, and during the short rainy season, particularly in October, December, and January, both in terms of quantity and volume. During certain times of the year, severe rainstorms with overland flow are more common. Nevertheless, during the months of April and May, the significant contribution of events with less rainfall may impact soil moisture status prior to the rainfall event, as shown in Fig. 9.5. Sakarani Mission's monthly rainfall (West Usambara Mountains, Tanzania) is classified into three categories: 10 mm, 10-20 mm, and > 20 mm.

180 Leo Stroosnijder is increasing the likelihood of overland flow caused by both infiltration excess and saturation excess. Hoogmoed and Stroosnijder (1984) obtained comparable findings during four years of observation (1976-1979): showers 10 mm contributed 21% of total rainfall, showers 10-20 mm contributed 27%, and showers > 20 mm provided 52%. To determine the return period of 24h rainfall, the maximum 24h occurrences each month of Kwalei rainfall from

September 1991 to August 2001 were analysed using Gumbel's probability distribution. The 117 observations' Gumbel's distribution yielded the following equation:

(-ln(-lnk)) + 15.28 (with R2 = 0.95) = Xb (1)

Where Xb is the 24h event boundary and k is the chance of failure.

The 'design' rainfall for a 25-year return period is 67 mm using this calculation.

Despite the decent regression coefficient, the uncertainty increases for large rainfall levels. For example, the occurrence of 21 October 1997 (120 mm) would occur once every 600 years, according to this distribution. It is evident from this that caution should be exercised when extrapolating return durations.

The success or failure of a crop is determined more by the distribution of rainfall over the growth season than by the total amount of rainfall during that time period (Sivakumar 1991). An examination of the likelihood of dry spells is one way for characterising the 'goodness' of this distribution. A dry spell is defined as a time without effective rain in meteorological analysis (using Markov chain methods). A dry spell is defined in agricultural terms (using a water balance model) as a sequence of consecutive dry days that results in a soil water deficit that causes crop water stress (Barron 2004). Depending on the soil's waterholding capacity, meteorological analysis either overestimates or underestimates agricultural dry spell analysis. According to Barron et al. (2003), a dry period lasting 5-15 days is damaging to Sub-Saharan Africa. A 10-day dry spell in Kenya and Tanzania has the potential to harm a corn harvest owing to a lack of water.

In agronomic modelling, crop development is frequently predicted using daily meteorological data (Stroosnijder and Kiepe 1998). The soil water, which is dispersed over numerous soil layers. Rainfall and Land Degradation the plant roots extract 181 layers, with the driving power being the differential in the water potentials of the soil and the leaf. This enables exact estimation of the influence of land degradation on agricultural productivity.

In hydrological modelling, the fraction of daily rainfall that infiltrates into the soil must be specified. This is determined by the physical conditions at the soil's surface. Degraded soils frequently have a crust that prevents infiltration. Tilling these soils will help to break up the crust and promote infiltration. No-till farming, which is frequently promoted to alleviate land degradation, is not a feasible choice for such soils. Stroosnijder et al. (1994) estimated runoff for a millet crop in Mali during 35 growing seasons (1950-1984) using no-till and conservation plowing (CT, i.e. regular crust-breaking). According to Fig. 9.6, the average runoff for no-till was 36.5% of rainfall (SD = 3.4%), whereas CT decreased runoff to 25.6% (SD = 4.8%). The difference represents 37 mm of accessible water. Y water (rill + interrill) best corresponds with rain kinetic energy multiplied by maximum 30-minute intensity. There are several formulae available for determining rainfall kinetic energy using rainfall intensity. VanDijk et al. (2002) provide a review and recommend using KE = 0.283 (1 - 0.52 * e-0.042 * I) with KE in MJ ha-1 mm-1 and I in mm h-1. All KE = formulae level off at 0.30 MJ ha-1 mm-1 when I > 50 mm h-1. Showers with intensities less than 10 mm h-1 are generally thought to be non-erosive.

A study of the geographical and temporal distribution of rainfall features in the La Encaada watershed in north Peru from 1995 to 2000 indicated that the mean annual rainfall was 600 mm in the neutral years (9/95-3/96 and 9/96-3/97) (Romero et al. 2006). Nevertheless, the yearly total grew during El Nio (9/97-3/98) and La Nia (9/98-3/99 and 9/99-3/00) years, with the highest reaching 1200 mm. In general, rainfall intensities were quite low, with 96% of incidents registering less than 7.5 mm h-1. Yet, during the El Nio year, the number of high intensity episodes rose (18%) in the lower section of the watershed, where they were ordinarily just 4%. The La Nia year was distinguished by high overall rainfall but moderate intensity.

An erosivity analysis (Table 9.4) revealed that rain episodes are more erosive in the lower section of the watershed, particularly during atypical years such as El Nio. Depending on the year, there was some regional fluctuation in the amount of rainfall falling at various altitudes. This variance appears to be connected to terrain as well as phenomena such as El Nio/La Nia, which influence wind circulation and the convective movement of air masses. Regions at risk of erosive events can be identified within the watershed, but soil reaction is affected by numerous other factors, including soil type, slope, and vegetation. Rainwater collides with the ground near the soil surface. Rainfall is distributed throughout numerous hydrological compartments

Section 9.1 suggested that farmers' perceptions of drought may be explained as a shortage of accessible water caused by degraded soil physical attributes such as soil depth and waterholding capacity. Keyantash and Dracup (2002) determined that the 'computed soil moisture' performed best according to six weighted selection criteria after examining a range of agricultural drought indices. The "computation of soil moisture" will be illustrated in this part. Because land degradation (of which soil erosion is the primary cause) reduces infiltration, waterholding capacity, and transpiration while increasing runoff and soil evaporation (Stroosnijder 1992), special consideration will be given to estimating the effect of land degradation on 'computing soil moisture'.

The water balance in the field

The latter is determined by soil type, soil properties, soil surface condition, and moisture content. While soils are dry, the IR is high; as they wet, the IR drops until it reaches a constant rate, known as the terminal rate or final IR. Its final-IR value is high for sand (> 50 mm h-1) and low for clay (10 mm h-1) (see Morgan 2005). The expansion of clay soils may also cause low IR. It will also be lowered if soil organic matter is lost owing to land degradation, and it may be drastically reduced if the soil has a crust, as demonstrated by Hoogmoed and Stroosnijder (1984). (due to land degradation). If the surface crust is impermeable, yearly runoff on deep coarse soils can reach 13% (Rockström and Valentin 1997).

The water balance of the soil

Water held in the root zone may be lost (negative value of S) due to evaporation from the soil surface into the atmosphere (E), or it may be taken up by plants and lost through transpiration (T). The soil water balance reflects this:

$\Delta S = E + T$ (4) (4)

The rate of evaporation (mm d-1) is determined by the moisture content of the topsoil, the drying power of the atmosphere, and the extent to which the plants shade the soil. The Leaf Area Index is a proxy for the latter (LAI). Under semi-arid circumstances, Stroosnijder (1987) established and verified a simple equation for E. E can be approximated as 2 mm d-1 throughout the short growing season (of around 100 days) in semi-arid conditions as a parametric approximation for crops with a LAI of 1.

Plants in semi-arid areas may typically yield with minimal water. Millet growing in West Africa is one example. The grain harvest is around 500 kg dry matter (DM) ha-1, while the straw and roots harvests are each 1000 kg DM ha-1. As a result, total dry matter is 2,500 kg DM ha-1. Millet utilises water effectively since it has a C4 photosynthetic process. The transpiration coefficient is 200 kg water per kilogramme of dry matter. The total crop use is thus 2500 * 200 = 500 000 kg water ha-1. It's merely 50 mm ha-1. During a 100-day growth season, E is frequently equivalent to 200 mm while T is just 50 mm.

This is due to the poor utilisation of precipitation. According to Stroosnijder (1982), the greatest quantity of water stored in the root zone that is accessible for plant development (i.e. that plant roots can draw from the soil) is a critical soil attribute since it impacts plant survival during a dry spell (i.e. periods of consecutive days without effective rain). TAW in the rootable region of the soil profile is calculated as TAW = RD * 0.9(FC WP) (5), where RD is the rootable depth (mm) and WP is the wilting point, i.e. the moisture content if the water potential equals -1.6 MPa (pF 4.2).

Plants in soil at WP will die, therefore the 0.9 safety factor. In a nondegraded soil with average physical qualities, for example, the root zone soil depth may be 600 mm and (FC-WP) = 0.13. As a result, TAW = 70 mm. With an actual evapotranspiration (ET) of 2.5 mm d-1 (E = 2 + T = 0.5), the water reserves for a crop outlined above are sufficient for a 28-day or 4-week dry period! Of course, this is only true if the soil moisture content was entirely recovered before the dry season began. The root zone soil depth is frequently decreased in degraded soils because topsoil has been lost by erosion. Moreover, the soil texture has gotten coarser as a result of the selective removal of finer particles, and the structure has degraded as a result of the loss in soil organic matter. In the preceding example, this results in a root zone soil depth of 400 mm and an FC-WP of 0.10. This suggests that TAW is just 36 mm, which is insufficient for 14 days or two weeks! Farmers refer to a 'drought' problem as a difference in the length of the dry period that plants can withstand.

Drought perception among farmers

Drought was highlighted as one of the primary reasons for a drop in land production during recent studies on Soil and Water Conservation (SWC) in the Sahel, Kenya (Biamah 2005), Ethiopia (Tesfaye Beshah 2003), and Tanzania (Hella and Slegers 2006). Farmers' perceptions of drought are heavily impacted by and vary according to local environmental circumstances, as well as among individual farmers within the same village, based on the peculiarities of their own farms. This shows that the idea of drought is contextual for farmers. It has even been advocated recently that drought be considered a social construction. McMahon and Finlayson (2003), for instance, remark that "droughts are not easily characterised other than by culturally motivated perceptions about the magnitude and kind of damage".

Farmers associate drought mostly with the incidence of dry periods. Some recent studies have shown minimal indication of an increase in the length and/or frequency of dry periods. Seleshi and Camberlin (2006) discovered no changes in the yearly maximum length of Kiremt and Belg dry periods over Ethiopia using daily rainfall from 11 important locations from 1965 to 2002. Mazzucato and Niemeyer (2002), Conway et al. (2004), and Romero et al. (2004) all reached similar findings (2007).

We must therefore search for another reason for why farmers today consider dry times to be more dangerous than in the past. I believe they perceive a scarcity of accessible water as a result of degraded soil physical qualities such as soil depth and waterholding capacity. Green water is rainwater that has been held in the soil and is now available to plants. Infiltrating water can be retained in the soil as green water or it can drain to groundwater and stream bed flow. All physical, chemical, and biological soil qualities alter and impact the field water balance directly and indirectly as a 'natural' landscape is transformed into a 'culture landscape'. Food crops, for example, cover the soil for part of the year and hence use less water for transpiration than 'wild' vegetation, which covers the soil all year.

The excess water either percolates through the soil to the groundwater (producing higher water tables) or runs over the soil surface as overland flow in sheet flow or in rills, generating new drainage routes (gullies) with inherent erosion.

GWUE declines owing to changes in land cover as well as deterioration of physical soil quality as a result of land degradation (mainly due to a decrease in soil organic matter). As rain falls on bare soil, the soil aggregates break apart. Because of the surface crusting, only a tiny percentage of rainfall can permeate the soil; the majority of it flows off the soil surface and is thus wasted for biomass formation. The proportion of rain that is efficiently utilised by plants declines while the proportion that discharges increases due to a complicated mix of both direct and indirect soil physical/hydrological processes. According to Pimentel (2006), reduced water availability owing to land degradation and soil erosion is a serious worldwide agricultural and environmental issue.

There are several methods to define water usage efficiency (WUE). PUE is defined as the yield divided by the precipitation (perhaps compensated for variations in stored water between following years: S). PUE is measured in kg ha-1 mm-1 and varies from 4 (low) to 10 (high) (improved). PUE is very effective in agricultural systems with a high harvestable yield. Yet, in a broader discussion of 'ecosystems,' particularly in connection to the problem of regreening (and related carbon sequestration in soils), the total amount of biomass generated is what matters (Stroosnijder and Hoogmoed 2004).

There is a strong link between the quantity of biomass produced and the amount of water transpired for a specific species and location. As a result, in terms of water usage efficiency, the idea of Green Water Use Efficiency (GWUE), represented as the proportion Transpiration / Precipitation, is more relevant. The GWUE in dryland areas in Sub-Saharan Africa ranges from 5 to 15%. It may reach 20% in East Africa, while it may top 50% in semiarid but equivalent climates in the United States.

Mitigation of dry spells and enhancement of GWUE

The purpose of GWUE optimization is to maximise the useful flow of water as plant transpiration while minimising non-productive water flows such as soil evaporation, runoff, and percolation beyond the root zone. In-situ water conservation and on-farm water harvesting have already been advocated and practised 40,000 farm ponds have been built in northern Ethiopia alone in the last two years), but adequate attention to the optimal use of that conserved water is frequently lacking.

How can the use of rainwater be made more efficient? The overall conclusion of this analysis is that widespread land degradation remains difficult to demonstrate, particularly at the regional, watershed, and farm levels. Rainfall closely follows vegetation and plant cover, and African terrestrial ecosystems have shown to be more robust than previously anticipated. But, at the point scale, it appears that physical soil properties are worsening. This has implications at the soil surface, where rainfall and land collide, and rain is distributed across many pedo-hydrological components. One cause for the existing low green water use efficiency, i.e. the low proportion of rainfall used in transpiration contributing to biomass production, is most likely the intrinsic poor quality of most African soils.

Rainfall investigation at various scales has likewise indicated significant variability, but no clear trend in relation to climate change. Yet, continued deterioration of soil properties will have an impact on the quantity of water that can be stored in the root zone and drawn on to endure dry spells. Farmers' fears about drought turn out to be an issue of coping with dry spells, as there is no indication of a large rise in the length or frequency of such spells. Soils appear to have altered and are now less capable of giving crops with water during the dry spells that are so common in African semi-arid regions.

Land Degradation Trends. We must scrutinise the 'hard data' from remote sensing, models, and measurements rigorously, keeping in mind that trends in land degradation are appraised differently in different regions of the world. Classical approaches can readily lead to doomsday conclusions, while modern methodologies provide a more balanced view of land deterioration. Current definitions of land degradation and desertification must be revised in light of new scientific discoveries such as: (1) the concept of ecosystem services, (2) the need to distinguish between land degradation and 'land development' as a result of economic development, and (3) the contextualization of land degradation.

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The relationship of climate, human activity, and land condition is complicated. Climate influences the amount to which land management methods impact the state of the land, and climate also limits the spectrum of land management strategies that may be used sustainably. These interactions and their repercussions have been proven to have ramifications for the atmosphere and future climate. As a result, while addressing climate change and land degradation, it is crucial to understand the complex processes of feedbacks that occur at various temporal and geographical dimensions. Many of these processes and feedbacks are still poorly known, thus sustainable practises must be developed against a backdrop of limited scientific understanding and uncertainty about future climate change.

Yet, there are compelling reasons to act. It is commonly acknowledged that land use methods must minimise soil degradation in order to be long-term sustainable. Climate change is also commonly acknowledged to play a significant role in the deterioration of productive and natural areas (206 Beverley Henry, Greg McKeon, Jozef Syktus, John Carter, Ken Day, and David Rayner). Many of the nations most impacted by land degradation are already economically disadvantaged, and their ability to absorb a drop in output is restricted. Yet, land degradation is a worldwide problem that affects both affluent and poor countries. It is vital for economic and environmental sustainability to understand how climatic variability has contributed to resource degradation and how present and future climate change may worsen the harm. Further study into global and regional climate systems, seasonal forecasting, climatic trends, risk assessments, and risk communication to land managers is highlighted in this section. Decision support tools and policy formulation based on strong science are required for land use that is both sustainable and productive.

A multitude of definitions of land degradation and desertification have been offered, and the term chosen will have an influence on how climate is interpreted. The definitional question, however, will not be addressed in this work. The United Nations Convention to Combat Desertification (UNCCD) defines land degradation as a "reduction or loss, in arid, semi-arid, and dry subhumid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest, and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activity." The UNCCD further defined desertification as "land deterioration in the arid, semi-arid and dry subhumid zones arising from multiple sources, including climate fluctuations and human activities". The role of climatic variability is the subject of this research.

The socio-economic dimensions of land management in dryland regions, where profitability and long-term production are frequently marginal, add to the scientific complexity of the problem. We do not attempt to discuss all elements of this topic in a single study since it is impossible. Rather, we offer one way to analysing and resolving the link between climate and land degradation based on our Australian experience. According to the United Nations Development Programme (UNDP), there are 54 million km2 of drylands worldwide, accounting for nearly 40% of land area. Australia accounts for around 15% of the total, with Asia (34.4%), Africa (24.1%), and the Americas (24%). While all drylands are at danger of deterioration, determining the level of degradation at any one moment is challenging, generating definitional issues once more (Prince 2002; Walker et al. 2002). Maybe the UNCCD estimate sums up the severity of the situation best: approximately 250 million people are directly affected by land degradation, and one billion people, many of whom are already living in extreme poverty, are at danger in over 100 countries.

In the following discussion, we will concentrate on the dry and semi-arid rangelands utilised for grazing domestic animals in Australia, which cover around 406 million hectares. European colonisation in Australia, which began a little more than 200 years ago, had a significant influence on the terrain. Nevertheless, trustworthy records are only available for a limited time (i.e. a little over 100 years). Land degradation occurs across a variety of time frames and can be linked to both natural and man-made causes.

207 elements and human activity: Climatic Variability, Climate Change, and Land Degradation. Identifying the causes of changes in land condition is difficult since natural temperature variations and other, frequently related, natural processes like wildfires interact with human-caused variables like overgrazing, the invasion of animal and plant pests, and the inappropriate use of fire. A large investigation into eight well-documented events of deterioration in Australia's rangelands gives insight into the environmental and human elements that led to specific regional occurrences (McKeon et al. 2004). After a discussion of what we learned from analysing those historical occurrences, we present preliminary studies on how land use, land use change, and climate change may enhance the likelihood of future land degradation. We offer an example of a dynamical climate modelling experiment in which feedbacks promote regional land degradation, exacerbating drought conditions in central Australia. Further study into how land degradation and climate feedbacks work through the carbon, energy, and water balances will allow dynamical climate modelling to produce more accurate climate forecasts in the future, supporting sustainable resource management.

Australia's risk of land degradation

Agriculture continues to be the most important land use in Australia, accounting for 61.5% of the land area (7.6 million hectares), with 56% used for natural vegetation grazing and the remaining 2.5% used for dryland grazing on developed pastures (SOE 2006). The rangelands of Australia are ecologically varied landscapes that are vulnerable to the effects of rainfall fluctuation. Rainfall in Australia is not only exceedingly low, with over half of the land area getting less than 300 millimetres of median annual rainfall, but it is also very variable on periods ranging from intra-seasonal to multi-decadal and beyond. The El Nio-Southern Oscillation, or ENSO, is a key cause of fluctuations in rainfall on inter-annual timeframes (e.g. Nicholls 1988), notably in the continent's north-east.

The combination of agricultural land use and high natural climatic variability in Australia, notably the frequency of severe and prolonged drought episodes, poses a challenge for sustainable land management. As a result of this problem, there has been a national and regional emphasis on policy and research into natural resource management and climate science, which offers a solid framework for reacting to climate change. Australia, for example, has adopted a National Drought Policy that encourages rural land managers to prepare for climatic variability while also providing financial aid to farmers in "Exceptional Conditions," i.e. unusual and severe drought episodes. The current definition of an extraordinary scenario is one that is unusual and severe, expected to occur once every 20 to 25 years on average, and produces a significant drop in farm revenue over a lengthy period of time.

The Australian Bureau of Meteorology offers climatic data and seasonal outlooks that help farmers and graziers to proactively reduce the risk of environmental and economic harm to their properties during unfavourable seasons. The Bureau's data is supplemented by application-driven information provided by private companies and state governments, such as the Queensland Government's Long Paddock website, which provides rainfall forecasts and probabilities for pasture growth for the coming season. The Commonwealth government coordinates the National Agricultural Monitoring System (NAMS), which pulls together a huge quantity of information from national and state organisations for land management. The NAMS data assists in the creation of risk management plans as well as proposals for Drought Extraordinary Circumstances funding assistance.

State governments in Australia are in charge of land management. This research focuses on Queensland (northeast Australia), where grazing domestic animals occupy approximately 85% of the 173 million ha land area. The majority of this area is covered by semiarid to arid grasslands and forests. The likelihood of long-term deterioration is also connected to overall grazing pressure from a combination of domestic cattle, native herbivores (especially macropods), and feral animals such as rabbits, goats, and camels in these rangelands. Other components in the land degradation equation include fire frequency management, woody vegetation growth, weeds, and vegetation clearance. The approach is based on the following principles: maintaining a comprehensive programme of land and vegetation condition monitoring using both remote sensing and field assessment; modelling rangeland systems to understand biophysical processes in historical, present, and future contexts; modelling regional climate systems and providing climate projections on seasonal and longer timescales; and engaging with government and the community.

This strategy exemplifies the key factors of mitigating the risk of land degradation under a changing and unpredictable climate:

An objective assessment of land condition, as well as an analysis of how current conditions compare to historical conditions; An understanding of the climatic and socioeconomic factors that contribute to productivity loss, degradation, and recovery of land and vegetation resources; z Climate risk assessments based on seasonal and longer-term outlooks, as well as an understanding of the reliability of these climate projections; and Information and education on the risk of land degradation.

The objective evaluation of land condition across the vast and diversified landscapes that characterize Australia's vast grazing areas necessitates the use of novel monitoring tools. In Queensland, an intensive remote sensing programmer (Statewide Landcover and Trees Study, SLATS) detects and maps woody vegetation change (clearing or regrowth) using intermediate resolution (25m x 25m) Landsat images (www.nrw.qld.gov.au/SLATS). Landsat analysis are combined with other products such as MODIS images to monitor resources at different geographical and temporal scales. Rangeland condition is determined by analysing foliage projective cover and the area of bare ground.

Although bare ground (or ground cover) is occasionally employed as a proxy for land condition, time series of remotely sensed data can be difficult to interpret, even when trends in an index are properly observed. For example, an increase in cover on grazing fields may be misinterpreted as an improvement in land condition when it is really due to weed infestation rather than an increase in cover of edible perennial grasses. Field validation is essential for validating the interpretation of remotely sensed pictures. Land managers must be convinced that remote sensing can properly monitor the danger of land degradation, and field verification is critical in establishing the technique's adoption. Furthermore, experience in Queensland has demonstrated that it is critical to establish continuing field data gathering programmes to facilitate objective monitoring of land status. Transect and point measurements are used to calibrate remote sensing programmes and process models in Queensland for monitoring the risk of land degradation in extensive semi-arid and arid grazing lands and providing advice for managing the risk of land degradation in a variable and changing climate.

These statistics, which are backed up by detailed photographic archives, give a useful record of field conditions. Complementary field and remote sensing programmes provide objective and dependable monitoring of climatic and management impacts on arid and semi-arid areas utilised for broadscale grazing. Understanding the changes in the state of these lands, on the other hand, necessitates a comprehension of the biophysical processes that influence landscape conditions. In dry and semi-arid environments, accessible water typically controls plant growth, which effects the availability of feed for domestic animals and other herbivores, as well as susceptibility to soil loss through ground cover. To offer a foundation for analysing how the landscape operates, a process model that captures plant function and soil water balance is necessary.

The Australian Grassland and Rangeland Assessment by Spatial Simulation (AussieGRASS) model was created to track grass production and land cover, as well as to assess the influence of climatic variability on grazing areas. In the operational system, AussieGRASS runs a calibrated and verified water balance and pasture growth model on a 5 km grid across the continent, albeit data availability typically greatly restricts the accuracy of simulated values in huge broadscale grazing businesses. Aussie GRASS is based on the GRASP deterministic, point-based, daily time-step model, which simulates soil-water, pasture development, and cattle or sheep production. Other indicators, such as carbon stocks and grass cover, are simulated, making the framework a useful environmental calculator for rangelands.

Total precipitation only offers a partial picture of drought consequences, but pasture response, as assessed by growth, biomass, and cover, provides a more accurate picture of the impact of drought on rangelands and a more realistic evaluation of present circumstances in a historical perspective. Pasture growth incorporates various environmental parameters such as temperature, humidity, solar radiation, and rainfall pattern, as well as the ecosystem's starting state (especially grass basal cover and soil moisture).

AussieGRASS provides near-real-time pasture simulations and is coupled to a seasonal climate prediction system (currently the SOI-Phase system, Stone et al. 1996) to offer three-month outlooks. AussieGRASS can estimate grazing pressure and so suggest degradation risk and potential for enhanced management by taking cattle numbers into consideration. Climate risk assessments give information to land managers to enable proactive decision-making, and the information is also used to advise the government on the danger of land degradation during droughts. As a result, spatial modelling and climate risk assessment in arid and semi-arid rangelands may benefit enterprises and regions while also offering a fair and objective evaluation of pasture quality in various Australian locations. AussieGRASS is used to develop information products for land managers as well as to examine the effects of droughts. These items are made accessible in near-real time for the upcoming season. The process-based modelling approach, on the other hand, makes AussieGRASS a valuable generic environmental calculator.

As a result, AussieGRASS is used to analyse present and upcoming challenges vital to Queensland natural resource management, such as landscape water balance, climate change impacts, carbon stocks in plants and soils, and the influence of grazing on groundcover and sediment erosion. Research is ongoing to increase simulation accuracy and develop new applications to meet government priorities.

High-quality climatic data, both historical and projected for the future, are essential for analysing resource-conditioning processes. The Australian Bureau of Meteorology (BoM) publishes national meteorological data on a daily basis. The Silo project, a collaboration between the Queensland Government. Rangelands system components, applicable to the grasslands and woodlands that characterise northern Australia's extensive grazing lands, as simulated using the GRASP pasture growth and water balance model in the AussieGRASS spatial simulation framework 212 Beverley Henry, Greg McKeon, Jozef Syktus, John Carter, Ken Day, and David Rayner are among the cast members.

From 1889 to the present, BoM provides an uninterrupted time record of daily interpolated climatic data. Silo was founded in 1997 in response to the demand for long time series of daily climate data for use in biophysical modelling applications, specifically agricultural, water, and rangeland management. Silo enables spatial models like AussieGRASS to deliver evaluations of not just present land conditions, but also land conditions rated relative to circumstances across more than a century. It is vital to express present land conditions in connection to history to support drought policy where financial aid is based on 'unusual and exceptional' conditions. The method is also effective for demonstrating patterns and changes over time.

Historical data time series are also necessary for seasonal forecasting or climatic risk assessments based on analogue years, such as the SOI phase system (Stone et al. 1996). Statistical modelling is employed operationally to give climate risk assessments using the AussieGRASS framework, but dynamical systems may also be linked to the five km gridded surface, as discussed later in this chapter. Future advances in climate research will increase the accuracy of high-resolution climate change scenarios, which might be used inside AussieGRASS to model the impact of climate change on the risk of land degradation and production.

Recognizing historical land degradation in Australia's rangelands

An examination of eight well-documented occurrences of deterioration in Australia's rangelands has revealed information about the processes that lead to land and vegetation degradation (McKeon et al. 2004). Rainfall variability is a crucial factor, but land degradation involves more than just a lack of moisture during droughts. Similarly, recovery will not happen in a single good season, and controlling the end of a drought may be as crucial as managing the start of dry conditions in avoiding long-term harm to grazed landscapes. Understanding the pattern of climate variations, as stated in the preceding section, and the stresses on the land imposed by natural and human activities is therefore a first step in comprehending the sequence of events that precede the damage.

CHAPTER 9

WEATHER PATTERNS

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Australia's climate reflects its tropics/subtropics position (about 11o S to 39o S) and limited land mass in comparison to neighbouring waters. summarises climatic variation timelines important to delivering climate risk information for land management in north-eastern Australia. Climatic fluctuations, notably in rainfall, are caused by the chaotic structure of the climate system as well as the impacts of changes in sea surface temperatures and air circulation patterns the latter are rather predictable. Seasonal climate forecasts in this region are mostly based on a knowledge of the genesis of the ENSO phenomena and its influence on rainfall. The intensity of the ENSO-rainfall association, and hence the dependability of ENSO-based predictions, changes geographically and throughout the year. Farmers and graziers managing large-scale output in the face of very variable rainfall might benefit from more accurate rainfall forecasts or climate risk assessments. Even when the signal intensity is low, a grasp of regional climatology and the variability typical of the place is advantageous because it is recognised that a sequence of favourable years can lead to overestimation.

Assumptions of cattle carrying capacity, which contributed to previous periods of land degradation Extended periods of above or below median rainfall (more than three years) have a significant impact on the sustainable management of Australia's rangelands Stock and other herbivore populations have increased in various sequences of above-average years, such as the 1880s/90s, 1920s, 1950s, 1970s, and 1998-2001. As commodities prices fell sharply, graziers tended to hold onto stock in the belief that market circumstances would improve. Instances of similar price declines in Australia include the 1890s owing to worldwide recession, 1925 when wool prices dropped, 1929 due to a severe worldwide downturn, and the 1960s when wool and cattle prices fell again.

clined, and 1974 saw a drop in beef prices. High stocking rates and bad market circumstances made it more probable that dry or semi-arid rangelands would degrade if drought struck. A severe drought combined with large stock numbers might result in ground cover loss and resource degradation. Recovery can occur very quickly with a series of above-average rainfall years, but only if there has been topsoil erosion, seed depletion, and related long-term damage. In other circumstances, rehabilitation may take decades, or the resource may never return to its original form.

These studies emphasise the need of using an integrated strategy to estimating the risk of land degradation. While entering a dry spell, reducing stock numbers early will conserve ground cover and decrease deterioration. Knowledge on present conditions and seasonal outlooks helps to enable more sustainable management decisions, particularly on appropriate stocking rates. A seasonal conditions report, climate risk assessment, and drought alert are based on ground cover and pasture biomass monitored using satellite images and field data, in conjunction with seasonal climate forecasting systems and pasture growth modelling. Combining such assessments with information on stock numbers and overall grazing pressure allows the degradation risk to be evaluated and an alarm system for severe degradation to be provided.

Land degradation and climate change

Understanding of: (1) the impact of climate and management practises on land condition; and (2) the dependability of climatic outlooks are critical needs for climate risk assessment. Seasonal predictions have been established using statistical algorithms, however due to climate change, the past climate may no longer be a trustworthy predictor of future circumstances. The danger to land and vegetation, particularly in dry and semi-arid regions, may be larger than previously thought (IPCC 2007).

With a strong El Nio in 2002/03, Australia endured prolonged dry weather, resulting in severe drought in most of the east and south-west of the continent. At the time of writing, there had been no recovery to normal rainfall in several of these places (February 2007). Graziers have decreased stock numbers, but the prolonged drought has resulted in groundcover loss, tree death, dust storms, and other indicators of soil loss and land degradation.

Climate change is projected to make dry and semi-arid regions more vulnerable to deterioration. Droughts are becoming more frequent and severe as a result of global warming, according to mounting data. Drought conditions affected more than 30% of the land surface area in the early 1970s, up from 10-15% in the early 1970s (Dai et al. 2004). Precipitation has grown in high latitudes, notably in the Northern Hemisphere, whereas it has declined in semi-arid areas. According to a worldwide research, sudden changes in rainfall are more frequent in dry and semiarid regions, and this vulnerability is presumably connected to large positive feedbacks between plant and climatic interactions. The cause of rainfall loss in eastern Australia has not been determined (Nicholls 2006), however the observed patterns are consistent with wider changes found in the worldwide subtropics.

According to an analysis of the observed Australian climate record from 1950, mean surface temperatures have climbed by around 1o C on average, the frequency of heatwaves has increased while frosts have dropped, and rainfall has decreased in eastern Australia while increasing in the north-west.

There has been a significant and continuous rainfall deficit in eastern Australia over the last decade, and the lower rainfall conditions in Australia's south-west have persisted. Reduced yearly average totals of up to 20% are prevalent throughout wide parts of the continent. At the same time, considerable sections of north-western Australia have had an increase in rainfall of more than 30%. The ongoing shifts in rainfall patterns throughout the continent have put substantial strain on ecosystems and landscapes. The decrease in rainfall during this time period has resulted in even less soil moisture and a dramatic drop in environmental river flows. Less accessible soil moisture mixed with rising surface temperatures contributes to decreased plant growth and ground cover loss, increasing the danger of erosion. The potential flow to stream estimated by the AussieGRASS model using daily observed climatic data reveals a 40 to 60% decline across the continent

Climate risk assessment and forecasting ability have been found to be crucial in enhancing decision making in Australia's rangelands. Yet, climate risk information for Australia has been mostly focused on ENSO behaviour. The development of a climate forecasting capacity that can account for both human-induced and natural 218 degradation is a problem for predicting the danger of future land degradation. Greg McKeon, Beverley Henry, Jozef Syktus, John Carter, Ken Day, and David.

As well as natural climatic fluctuations, particularly on quasi-decadal to longer time durations. It is no longer viable to assume that the next 30 years will be a random sample of past climatic changes, and existing statistical techniques will need to be evaluated to see if they retain their competence in predicting ENSO formation and related seasonal rains. As a result, new methodologies are required to more correctly evaluate seasonal climate risk and give estimates.

Global Climate Models (GCMs) are increasingly being used to understand historical climate variability and to produce seasonal climate projections based on present sea-surface temperatures, i.e. global warming conditions. Improved historical datasets, such as those being generated by the Atmospheric Circulation Reconstructions over the Earth (ACRE) effort, will aid in the interpretation of natural climate fluctuations. The ACRE project entailed recovering old instrumental surface data and utilising it to improve and expand the time series of digitised records. This data will subsequently be used to underpin surface observations-based reanalysis with enough data coverage to be globally valid until the mid-19th century (Dr Rob Allan, Hadley Centre for Climate Change, Met Office, UK, Pers. Comm., and Compo et al. 2006). The reanalysis outputs are also intended to offer an observational foundation for analysing ocean-atmosphere model integrations modelling anthropogenic influences on recent climate, as well as enabling present and future climate change consequences to be examined against a trustworthy backdrop. Nonetheless, linking low resolution (e.g. 2o) climate models with historical climate data to construct high resolution (0.05o) spatial biophysical models remains a key difficulty for climate scientists (e.g. Syktus et al. 2003). The implications of various climate change scenarios may be examined using such models in order to enable the development of appropriate adaption measures for future conditions.

In summary, the risk of land degradation will be better managed if resource managers and government policymakers have (1) a better understanding of past trends and variability in rainfall and other climate variables; (2) plausible regional climate change projections; and (3) a foundation for resource managers and government policymakers to more confidently change decisions in response to a likely changing climate. Every year, significant portions of boreal and temperate forests, tropical forests, tropical and subtropical savannas, woodlands, and open forests are destroyed by fires on all continents. In Africa, approximately 168 million ha are burned annually south of the equator; in the United States, the ten-year average burnt area (1990-1999) was 1.5

million ha; and in Europe, the annual burnt area reached 740,379 ha during the 2003 drought. In recent decades, there have been more frequent, more severe, and extensive fires that endanger human security, ecosystems, and add significant amounts of greenhouse gases to the atmosphere, influencing climate processes. In addition to land management, these fires have been connected to hotter and drier weather as a result of climate change (Stocks et al. 1998; Bond et al. 2003). There is a need to improve our understanding of the impacts of fire on ecosystem production, particularly its relationship with land degradation and the resultant feedbacks.

Fire is a combustion process that requires fuel (in this example plants), heat (either human or natural), and oxygen to feed the chemical reaction (oxidation) that happens throughout the burning process (Stocks et al. 1997; Trollope et al. 2004). The process of combustion and the spread of fire are inextricably tied to meteorological conditions such as precipitation, temperature, and wind, which characterise fire weather. Influences on fire weather: MODIS on board the Terra and Aqua satellites discovered a buildup of active fires during a 10-day period. Each dot on the map is coloured to represent a place where MODIS identified at least one fire during the compositing period. The colour goes from red for a low fire count to yellow for a high fire count. (Credits: Jacques Descloitres, MODIS Rapid Response System at NASA/GSFC; Louis Giglio, fire identification method; MODIS Rapid Response System fire locations since mid-2001; and Reto Stokli, background picture)

Pre-fire factors that affect whether or not a fire will develop; the burning process, which pertains to the spread and intensity of the fire; and The post-fire phase, which includes the immediate and long term repercussions of fire. These climatic elements, in combination with other variables like as soil fertility, topography, herbivores, and land management in general, can enhance or reduce fire-weather risk and alter the effect of fire on the landscape.

Fire has long been recognised for its role in influencing ecological processes. For example, rainfall and terrain characteristics may shape forest distribution, but fire patterns impact forest location (Geldenhuys, 1994; Bond et al. 2004). Fire is regarded as one of the most significant renewing processes in practically all forest ecosystems under natural conditions. It is known to accelerate seed germi-nation in many Acacia species in semi-arid regions, and there are signs that fire smoke treatments may be useful in the proliferation of commercially important wild plants. Wildfire ignited by lightning clears old and dead trees in the boreal region, allowing space for new seedlings and increasing nutrient availability while maintaining age structure, species composition, and floristic diversity.

While fire's biological significance is well understood, its larger involvement in environmental processes and the ensuing feedback on climate and, ultimately, livelihood systems has gotten little attention until recently. Recent research has revealed that, in addition to its recognised biological features, fire is an essential land use tool, an increasing worldwide danger, and a role in climatic processes with feedback effects on land degradation. Land degradation has acquired widespread worldwide notice since the 1970s, following the terrible drought in the Sahel region and the subsequent founding of the United Nations Convention on Combating Desertification (UNCCD) in 1994. (MA 2005b; WMO 2005). The UNCCD described desertification as "land deterioration in arid, semi-arid and dry sub-humid lands resulting from many sources including climate fluctuation and human activity".

Land degradation is defined as the deterioration or loss of dry land ecological or economic productivity (MA 2005b). Changes in fire regimes caused by climate change are anticipated to increase vulnerability to land degradation in places such as the humid-temperate and boreal zones, which are not traditionally thought to be the most prone to this phenomena.

Drylands are distinguished by seasonal moisture patterns, which contribute to their vulnerability to fire. In these areas, water scarcity reduces plant productivity and other ecosystem provisioning functions. Drylands are home to one-third of the world's population, the majority of whom rely more heavily on ecosystem services than in any other region. Yet, around 20% of these locations are already deteriorated, and future growth scenarios indicate that land degradation would worsen if interventions are not implemented. Sub-Saharan Africa and Central Asia are the most susceptible regions. Land degradation affects 46% of Africa's surface area, and the majority of persons who live in these regions are impoverished.

Although fire happens quickly and has evident direct consequences, as opposed to the long and relatively imperceptible processes of land degradation, both processes are heavily influenced by climate and result in feedbacks on climatic processes. In addition to climate, geography and land use management play a role. The interaction between fire, land degradation, and climate linkages has several aspects and will grow more difficult as a result of climate change. Fire can degrade land depending on climate, geography, and other variables (MA 2005a and b). But, under some situations, soil degradation can also produce favourable conditions for fire to grow.

The purpose of this chapter is to illustrate the relationship between fire-weather danger and land degradation, as well as potential feedback loops. The chapter focuses on the function of fire weather in pre- and post-fire landscape impacts. Understanding the relationships between fire-weather risk, land degradation, and feedback loops in the current climate would presumably aid in modelling future trends and determining effective mitigation and adaptation strategies. The first portion of the chapter gives background information on the processes of land degradation, fire, and fire weather. The part on the function of fire in land degradation, the interaction between fire and land degradation, and the consequences of climate change follows. The third section discusses the importance of international collaboration in reducing the detrimental consequences of fire on the landscape.

The Issue of Land Degradation

Land degradation processes are caused by a loss in plant cover, such as frequent burning, and the resultant exposure of soil to soil erosion agents such as heat, wind, and water. This eventually leads to landscape fragmentation, loss of soil fertility, changes in vegetation species composition and loss of bio-diversity, salinisation in some areas, and siltation, which reduces reservoir capacity, increases susceptibility to flooding, and has a negative impact on fresh water fish production. Degraded regions are swiftly colonised by annual grasses and/or woody weeds (bush invasion) depending on the landscape and other conditions.

Climatic variables such as considerable inter-annual fluctuation in precipitation and harsh temperatures make dry regions more vulnerable to land degradation. Annual precipitation in some regions of the Kalahari Desert in Southern Africa deviates by up to 80% from the long-term average during dry years (Geist and Lambin 2004). Dry land regions contain poorly formed soils with limited organic content, making them extremely vulnerable to erosion processes when exposed (WMO 2006). Some studies have recognised the significance of socioeconomic elements, in addition to climate, in land degradation processes. Land use effects that undermine dry land ecosystem resilience typically worsen during drought periods when demand for ecosystem services considerably outnumbers supply. Land degradation is a multifaceted process involving several components, the most important of which are climatic variability and land use.

Fire characteristics that influence land deterioration

In general about 90% of bush fires globally are lit by humans (Main and Haines 1974; Frost and Robertson 1987; Pyne et al. 1996; Van Wilgen and Scholes 1997; Goncalves et al. 2006); some through arson, carelessness, prescribed burns, but majority of ignition sources are linked to population increase, livelihood systems practiced and the breakdown of traditional land management systems. The impact of fire on land degradation is determined by fire behaviour, which is affected mostly by weather but also by geography and human activity. Land management and herbivores can reduce fuel load or shift the vegetation structure, for example, from grasslands to woody layers with minimal herbaceous cover, lowering the danger of fire. Other land uses, such as wood cutting, can open forests and enhance fire vulnerability, as seen in the 1983 Indonesia fires (Pyne et al. 1996). The function of people in fire patterns occurs in a fire-friendly environment. Large fierce fires in the United States of America in 2000 were caused by human interventions such as timber harvesting and years of fire suppression, which led to the expansion of fire sensitive species such as Calocedrus decurrens (Torrey) and Florin (incense-cedar), as well as the severe drought that year (Franklin 2006).

Fire weather describes the conditions that allow fire to spread. Meteorological characteristics such as air temperature, precipitation, relative humidity, and wind speed are the fundamental aspects of fire weather (Van Wilgen and Scholes 1997). The effect of these variables on fire spread rates is consistent across regions. For example, savannas with fire fuel consumption ranging from 500g m-2 in arid zones to 1500g m-2 in sub-humid zones experience similar effects as humid boreal and temperate ecosystems with forest fuel consumption ranging from 4000-5000g m-2 (Stocks et al. 1997).

Topography may have a variety of effects on fire weather. Slope determines wind speed and direction, and it also effects fuel load through soil moisture (Geldenhuys 1994). Difficult terrain can modify the direction and variety of wind speed, impacting fire spread and suppression effectiveness (Geldenhuys et al. 2004). Fuel type and density are influenced by soil fertility and rainfall. The amount of rainfall and sun exposure are influenced by the aspect. Fuels positioned on sun-facing slopes are more likely to lose moisture quickly, posing a higher fire-weather danger.

Meteorological conditions play an important role in establishing the fire season, which is the time of year when the fire-weather risk is highest and fires are most likely to occur. In Botswana, south of the equator, the fire season begins in August and peaks in September before declining. Temperatures in Botswana are high from November to March, however few fires occur during this period due to high relative humidity (RH) and moisture in the fuel because it is the rainy season. The peak fire season in the African savannas north of the equator occurs in January, when rainfall is at its lowest, less than 25 mm.

Lighting fires are more common in Southern Africa between October and January, at the start of the rainy season, when thunderstorms are active. In contrast, the bulk of human-caused fires occur between May and September panning the winter to the dry season. Early dry season fires, which occur at the start of the dry season when the vegetation is still moist, are less dangerous than middle to late dry season fires, which occur when the vegetation has lost most of its moisture, the air temperature is high, and the relative humidity RH is low (August to October for much of Southern Africa) Frequent mid- to late-season fires are the most damaging because, in addition to reducing vegetation cover, they can damage seed banks and developing plants and disrupt soil qualities.

Fire has been classified into three types based on fuel types, particularly vertical projection, which is defined by climatic factors: ground fires that burn organic matter underground; surface fires that burn litter, grasses, and shrubs; and crown fires that cover the tiara layer fuels (Trollope et al. 2004; Govender et al. 2006). Other types of fire are classified based on their spread in relation to wind and their position in relation to the fire perimeter: a head fire is a surface fire driven by wind and thus burns in the direction of the wind; a back fire is a fire that burns against the wind and/or down slope; a flank fire is intermediate to the other two; and spot fires are caused by burning embers carried a distance from the head. Fire types are defined by the amount of heat energy created and retained during combustion, and as a result, they have varying impacts on flora and soil. Surface fires burning as back fires in grassland and savannas tend to retain high temperatures for a somewhat longer length of time than surface head fires, and as a result, they can suppress grass re-growth more than head fires (de Ronde et al. 2004). Lower-growing plants are severely harmed by both head and rear fires. Yet, when shrub heights grow, head fires have a bigger impact because they have a higher flame height than rear fires. On average, severe flames spread around 30-60 m min-1, however unusually fast fires of about 100 m min-1 have been recorded. In locations with lesser fuel loads, such as the savanna, intensity levels seldom surpass 20 000 kW/m-1, but boreal fires can reach levels of 50 000 to 100 000 kW/m-1. In South Africa's Kruger National Park, it has been observed that major flames require more than 3500 kg ha-1 of fuel in addition to the dry hot weather. Because the climate in arid to semi-arid and dry sub-humid places is very varied, so is the fire-weather risk, which influences fire intensity and plant sensitivity to fire. When extended hot and dry circumstances follow periods of significant fuel generation, such as ordinary to unusually rainy years, high fire intensity is encountered. The timing of a fire determines its intensity. A controlled surface fire in the Kruger National Park, July 2003. The fire destroyed the herbaceous layer and bushes up to 2m tall.

CHAPTER 10

LAND DETERIORATION AND FIRE WEATHER

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In developing countries, the need to use fire in land use management contributes to frequent fire outbreaks, whereas in developed countries, past fire protection programmes and increased public access to forests are some of the factors that contribute to large-scale fire outbreaks under high fire-weather risk. This section examines how the various fire behaviour traits mentioned above combine to impair ecosystem production and contribute to land degradation.

Fire's Impact on Vegetation

The effects of fire on vegetation are determined by a number of factors, including fire intensity, frequency, kind, and timing, as well as vegetation type and post-burn circumstances (Hall 1994; Hiers et al. 2000). Short-term fire decreases plant cover, but long-term consequences may include changes in vegetation structure and species composition, with implications for biodiversity and **overall landscape productivity**

Structure of fire and vegetation

The impact of fire on vegetation structure is determined by tree species, height, and diameter, as well as fire kind, timing, and frequency. Woody plants, in general, become more fire resistant as they grow taller. In grass fires, for example, in the savannas, high intensity and recurrent burning kills young woody plants and seeds. Ground fires cause root damage in shallow-rooted tree species. High intensity crown fires that occur during the late dry season can be extremely damaging to woody plants because they produce full combustion of leaves, destroying the aerial sections of trees and shrubs and limiting their ability to regenerate.

Emerge from the ground. Crown and surface head fires were shown to produce higher damage on shrubs in studies in the Eastern Cape of South Africa, with 75% decrease in phytomass compared to crown and surface back fires with 42% reduction. Fires in the late dry season in southern Africa limit the regrowth of Miombo species such as Baikiaea plurijuga and Guibourtia coleosperma (Geldenhuys et al. 2004). During the 1998 dry season fires, around 44% of the total population of P. angolensis Miombo forest species in Nagmiland, Botswana, was discovered dead. The Kruger National Park's frequent and intensive daytime controlled burning from 1957 to 1991 contributed to the loss of huge trees.

Herbivory, in addition to fire, may be contributing to the decrease of huge trees. Elephants, for example, kill enormous trees and collect dead plant debris on the ground, which is easily ignited. They convert forests into open woodlands that are vulnerable to fires. Others have also noticed that the consequences of fire on woody plants may be event driven in certain circumstances, i.e. the occurrence of a specific type of fire at a given threshold intensity may cause considerable damage in contrast to yearly fires that are below the threshold (de Ronde et al. 2004).

Despite this, recurrent burning gradually alters the plant structure to open shrub-woodland vegetation, which is a more fire-prone system due to increased grass biomass production. Loss of biodiversity is one symptom of land degradation, and it can be exacerbated by fire. Nevertheless, the impact of fire in biodiversity is complicated, and it is influenced by factors other than fire regime (defined as fire frequency, season, severity, area burned, and plant type) and post-fire circumstances. In East Africa, for example, Themeda triandra grows more frequently when fire is present and less frequently when fire is absent. However, because this plant is vulnerable to drought in a semi-arid habitat, less burning or complete protection will be preferable.

Since species have varying levels of fire tolerance, frequent fire has an impact on species richness. Developing insulating tissues in the juvenile stages, such as thick, corky bark and high wood moisture, and or formed subterranean swelling root systems that sprout coppice shoots following fire are examples of fire tolerance (Van Wilgen and Scholes 1997; Geldenhuys et al. 2004). In various conditions, fire may boost certain species while reducing or eliminating others (Van Wilgen et al. 2004; Savadogo et al. 2007). The richness of South Africa's Fynbos environment is maintained by periodic burning. Nevertheless, this is dependent on the fire regime; if the fire return interval is short, species such as serotinous proteas, which mature after 3-10 years, may not have enough time to collect seedbank for species continuity. Similarly, if the fire interval is extended, the serotinous proteas may go extinct because relatively few seeds form seedlings in the absence of postburn circumstances. Several species' reproductive phenology and overall flower output are affected differently by the fire season. Lightning-season fires have already been reported to promote more synchronised and delayed blooming among and among species in northern Florida longleaf pine savannas In longleaf pine savannas, most plants burned before mid-April developed blooms before May, but those burned later in the spring and summer did not produce flowers until July or August.

Plant regeneration is also influenced by fire season, as previously stated for woody plants

Some Fynbos understorey plants regrow better when exposed to fall fires (March-April) rather than winter fires (June, July and August). Recurrent winter fires may favour some Asteraceae species, which are known to inhibit other species and produce a fire danger environment if allowed to develop in large numbers. Yet, only an autumn burn may result in a high density of proteas, indicating the requirement for a combination of summer and autumn burns, as well as restricted winter fires, to sustain biodiversity. While high intensity summer fires in the southern Great Plains of the United States favoured C4 grasses over C3 grasses, this is thought to be due to differences in post-fire soil conditions such as increased temperature, reduced moisture, and reduced mineralizable nitrogen, C3 grasses were negatively affected by fire regardless of season. C4 grasses, in general, prefer warm, dry environments, have higher nitrogen utilisation efficiency (NUE), and store a greater proportion of their total N in belowground structures than C3 grasses.

The combination of fire and other landscape disturbances results in higher biodiversity loss and the development of land degradation. The slash and burn agriculture method in eastern Madagascar has resulted in the extinction of local species in favour of alien invader shrubs and herbaceous species (Styger et al. 2007). Because of the loss of soil water necessary to support plants during the dry season, low intensity early dry season burning can be deleterious if followed by intensive grazing of the emergent highly nutritious fodder in post-burn regions. The same might be said for regions of severe burn if they are followed by significant post-burn herbivory activity or insufficient rainfall, both of which result in recruitment failure.

The effect of fire on species composition in the herbaceous layer is characterised by a drop in perennial plants. Low grass species diversity in South Africa's Kruger National Park was linked to frequent and intensive daytime controlled burning between 1957 and 1991. Regularly burned regions are eventually dominated by fire resistant species, which have the ability to regrowth after fire and germinate seeds after thermal exposure. They are often annual and pioneer plants that establish themselves fast in burned regions.

In an effort to mitigate the harmful effects of fire in the Kruger National Park, a set of thresholds pertaining to fire patterns that, if surpassed, signify that burning will gradually lead to biodiversity loss were devised. These criteria were determined using the fire-return interval, the seasonal distribution of fires, and the ranges of fire intensity and area burned (Van Wilgen et al. 2004). Yet, for the fire-dependent longleaf pine savannas recognised for having the greatest levels of endemism in North America, it has been suggested that a variable fire regime (i.e. variety in fire seasons) may be a better method to conserve biodiversity than relying on a certain fire season.

Fire's effects on soils, like those on biodiversity, are complicated and vary depending on soil characteristics, soil moisture, slope, fire regime, fuel load, and post-burn circumstances. Fire has an impact on both the physical and chemical aspects of soils, especially the productive soil layer. Changes in soil physical qualities result in the loss of productive soil, higher runoff during wet periods, reduced underground water recharge, which increases water deficit during dry periods and consequently intensifies drought during dry periods. These alterations eventually lead to the observed changes in vegetation structure, species composition, and overall biodiversity reduction, all of which are characteristics of land degradation.

Degradation of soil physical characteristics

The effect of fire on soil physical properties results from indirect effects related to loss of above ground biomass, which exposes the soil to soil erosion agents such as sunlight, wind, and rainfall/water, resulting in soil degradation. In African savannas, fires can kill 70-90% of the herbaceous standing crop and grass litter, exposing much of the soil (Frost and Robertson 1987). Infiltration rates have been observed to be substantially lower on sites that have been burned regularly for many years than on neighbouring unburned sites, owing to changes in soil surface structure.

With coarse-textured soils, a water repellent layer may form in the soil profile, resulting in reduced runoff. Water repellency results from organic matter being converted into a vapour phase during combustion and then condensed and chemically bound to soil particles. Leaching happens in steep slope locations, as does the loss of small particles down slope. In such conditions, even light rain showers might cause severe runoff due to low infiltration ability. On steep slopes, frequent high-intensity fires should be avoided. Reduced infiltration results in a low water table, low soil moisture, and increased siltation down slope, which enhances floods susceptibility (.

One of the direct consequences of fires on soil is the loss of soil moisture, particularly within the top soil layer, which has a detrimental impact on plant productivity. Because soil has a limited thermal conductivity, temperatures observed at 2 cm below the surface seldom reach 35o C, and below this depth, there is essentially no temperature rise, particularly for savanna fires, which are normally of lower temperatures. Nonetheless, post-fire soil temperatures can be much higher than in unaffected regions, with variances of 80o C compared to 23o C observed. These high temperatures, along with increased wind speed on bare post-burn sites, cause fast loss of soil moisture in the top soil layer, which is often the most significant in plant formation. Fire is anticipated to have a significant impact on soil moisture in dry and semiarid environments where water is already a key limiting factor in plant development.

Chemical characteristics of soil

Fire's chemical impacts are likewise quite complicated. Severe repetitive burning has a detrimental impact on soil chemical characteristics, initially through the loss of soil organic matter, which leads to mineral nutrient loss through leaching, however this varies depending on the kind of fire, soil, and plant. In Ethiopia, decreased carbon concentrations in the soil profile and relatively high soil respiration were discovered in seldom burned forest and woodland systems compared to fire-prone grassland systems, implying carbon loss during dry season fires and consequences for nutrient cycle. Nonetheless, there may be an increase in organic matter in some circumstances due to the deposition of dried leaves and charred plant components in fires that harm the forest canopy.

In savannas, where soil nutrients are concentrated on the surface soil, fire-induced erosion causes nutrient depletion as well as reductions in soil depth and water holding capacity. Because it is the most exposed to the thermal impacts of fire, the top layer of soil is the most impacted. Others have remarked, however, that in the case of savannas, where grass cover predominate, the effect of a few dry season fires on soil nutrients can be minimised since the development of most grasses is slowed and nutrients are transferred to subterranean storage organs. The impact of fire on soil chemical characteristics may be split into two categories: (i) fast mineralization of organic matter into ash, and ii) changes in microclimate that alter breakdown and mineralization rates in the near run, fire drastically reduces soil microbial biomass. Burning has been shown to favour bacteria over fungi, which are less fire resistant.

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Fire Weather and Land Degradation

First, fire releases mineral nutrients in the form of ash into the top soil layer, making them easily accessible to plants. The fertilising impact of fire, which is partially due to the increased prevalence of N-fixing bacteria following wildfires, and a rise in soil pH connected to an increase in exchangeable cations in soil, explain why slash and burn is used and why regrowth is so rapid in post-burn locations. Annual plants respond more quickly to increasing nutrition levels following fire than native perennial plants.

Mineralization has a short-term influence on productivity, usually lasting just for the first few weeks of the growing season. It is affected by soil qualities, the amount of vegetation turned to ash, the weather, and the frequency and severity of fires, among other things. Since ash disposal only lasts around 2-3 weeks after a fire, it is not a long-term source of nutrients. If moisture levels are extremely low, this temporary fertilisation may not be employed and may be carried away by the wind. Because of the quick loss of nutrients in sandy soils, nutrient pools may diminish after a fire. Hall discovered that nearly 100 times more calcium and magnesium, 30 times more phosphorus, and 20 times more potassium were lost in runoff from burnt plots in an Australian forest area, indicating that significant nutrient movement can occur due to burning, resulting in soil productivity loss.

Nitrogen loss from top soil can approach 96% of the amount available, especially when fire temperatures exceed 400o C. Nitrogen loss due to volatilization and leaching becomes a significant limiting factor for plant development and cannot be compensated for by mineral disposal (Hall 1994). Legumes (plant-fixing nitrogen) can compensate for part of this nitrogen loss if proper circumstances are available. Phosphorus, on the other hand, which has been discovered to have a role in encouraging tree growth following fire, has a greater temperature volatilization, up to 500o C, and is less vulnerable to leaching (Frost and Robertson 1987). Nitrogen and phosphorus are the most essential elements limiting plant community productivity in dry to semi-arid areas, second only to water (Billing et al. 2003).

Intersection between fire weather and land degradation

During a drought, increased land use pressure depletes plant cover and exposes the landscape to soil erosion agents. As the rains come back, depending on the severity of the problem and other criteria such as soil type, these regions are overtaken by rapidly growing, highly combustible annual and pioneer species, much as they do in areas of frequent burning. As a result, while fire can be an agent of land degradation, land degradation can also offer circumstances that decrease fire intervals, resulting in a land degradation-fire cycle in the area. During protracted drought, the land degradation-fire cycle may be stopped due to lowering fuel loads, but it may reappear with the arrival of rain since invaders will be quick to recruit before native species can establish themselves.

Pauline

When the effect of fire is paired with other land use pressures, land degradation is aggravated (Dukes and Mooney 1999). Studies in semi-arid sections of Argentina discovered that soil carbon in burnt non-grazed areas rose by 16%, compared to burned and overgrazed sites, which lost 38%. Reduced fallow season under slash and burn technique in Madagascar from 8-15 years to 3-5 years during a 30-year period resulted in loss of rainforest flora and eroded soils invaded by Aristida and Hyperrhenia grass species. Annual burning to manage pasture for cattle grazing in these places contributes to the perpetuation of a fireland degraded ecosystem. Whereas in southern Europe's Mediterranean basin, a combination of overgrazing and fire on mountain ranges puts the area at danger of catastrophic soil degradation.

Depletion of indigenous vegetation in drylands, caused by fire or other land use pressures, has in certain locations offered ideal circumstances for woody plants to outcompete grasses, resulting in the spread of woody weeds (or bush encroachment). Another sign of land deterioration is bush invasion. A long history of grazing in the Mediterranean basin of southern Europe resulted in the disappearance of indigenous forests and the colonisation of the region by phrygana vegetation, a very hardy shrub that reflects various phases of soil degradation. Overgrazed regions in Botswana are dominated by species such as Dichrostachys cenario, Acacia tortilis, and Melefera, however this varies depending on soil. Shrub-dominated areas have more soil loss and evaporation due to a lack of complete surface cover supplied by a herbaceous layer.

Fire releases mineral nutrients in the form of ash into the top soil layer, making them easily accessible to plants. The fertilising effect of fire, which is caused in part by an increase in the number of N-fixing bacteria following wildfires and an increase in the amount of N-fixing bacteria Increased soil pH is connected to increased exchangeable cations in soil, which helps to explain the rationale for slash and burn practises and rapid regrowth in post-burn regions (Gonzalez-Perez et al. 2004). Annual plants respond more quickly to increasing nutrition levels following fire than native perennial plants.

Mineralization has a short-term influence on productivity, usually lasting just for the first few weeks of the growing season. It is affected by soil qualities, the amount of vegetation turned to ash, the weather, and the frequency and severity of fires, among other things. Since ash disposal only lasts around 2-3 weeks after a fire, it is not a long-term source of nutrients. If moisture levels are extremely low, this temporary fertilisation may not be employed and may be carried away by the wind. Because of the quick loss of nutrients in sandy soils, nutrient pools may diminish after a fire. Hall (1994) discovered that nearly 100 times more calcium and magnesium, 30 times more phosphorus, and 20 times more potassium were lost in runoff from burnt plots in an Australian forest area, indicating that significant nutrient movement can occur due to burning, resulting in soil productivity loss.

Nitrogen loss from top soil can approach 96% of the amount available, especially when fire temperatures exceed 400o C. Nitrogen loss due to volatilization and leaching becomes a significant limiting factor for plant development and cannot be compensated for by mineral disposal (Hall 1994). Legumes (plant-fixing nitrogen) can compensate for part of this nitrogen loss if proper circumstances are available. Phosphorus, on the other hand, which has been discovered to have a role in encouraging tree growth following fire, has a greater temperature volatilization, up to 500o C, and is less vulnerable to leaching (Frost and Robertson 1987). Nitrogen and phosphorus are the most essential elements limiting plant community productivity in dry to semi-arid areas, second only to water.

During a drought, increased land use pressure depletes plant cover and exposes the landscape to soil erosion agents. As the rains come back, depending on the severity of the problem and other criteria such as soil type, these regions are overtaken by rapidly growing, highly combustible annual and pioneer species, much as they do in areas of frequent burning As a result, while fire can be an agent of land degradation, land degradation can also offer circumstances that decrease fire intervals, resulting in a land degradation-fire cycle in the area. During protracted drought, the land degradation-fire cycle may be stopped due to lowering fuel loads, but it may reappear with the arrival of rain since invaders will be quick to recruit before native species can establish themselves.

When the effect of fire is paired with other land use pressures, land degradation is aggravated. Studies in semi-arid sections of Argentina discovered that soil carbon in burnt non-grazed areas rose by 16%, compared to burned and overgrazed sites, which lost 38%. Reduced fallow season under slash and burn technique in Madagascar from 8-15 years to 3-5 years during a 30-year period resulted in loss of rainforest flora and eroded soils invaded by Aristida and Hyperrhenia grass species. Annual burning to manage pasture for cattle grazing in these places contributes to the perpetuation of a fireland degraded ecosystem. Whereas in southern Europe's Mediterranean basin, a combination of overgrazing and fire on mountain ranges puts the area at danger of catastrophic soil degradation.

Climate change, fire weather, and land degradation

The long-term impact of climate change on fire and land degradation, as well as the consequent interaction and possible feedbacks on the climate process, is of major concern. The link between land degradation and climate change is still unclear, and some suggest that dry land degradation is unlikely to contribute more than a few percent of overall greenhouse forcing found that fire is only cited as a cause of desertification one-third as often as lengthy drought spells. Further research is needed in light of future climate change-induced fire regimes and their impact on fireland degradation interactions and feedbacks.

Because of the effects on the quantity of carbon stored and released into the atmosphere, intense fire and land degradation can have a substantial impact on climate. Lal et al. (1999) estimate that land degradation reduces the soil organic carbon stock by 8-12 tonnes of carbon ha-1 on average in dry environments. Large-scale soil degradation has a significant impact on the global carbon budget, considering that the total carbon content of soil on the world is three times that of the atmosphere. Chapter 12: Fire Weather and Land Degradation the total carbon stored in terrestrial plants is 241 times more than the total carbon stored in fires. Since fire and widespread land degradation modify sources and sinks of greenhouse gases and influence the hydrological cycle, they can have a considerable impact on global warming.

The heat from burning flames raises the surface temperature, causing aridity due to the quick loss of moisture from the top soil layer and plants as it burns. The loss of vegetation over large regions, whether caused by fire or other land use-induced land degradation, decreases evapotranspiration, resulting in low latent heat flow and influencing climatic processes. Mineral dust in the atmosphere caused by desertification has also been demonstrated to have the capacity to affect both incoming shortwave solar radiation and outgoing longwave radiation, resulting in either a cooling or heating impact depending on cloud cover or the albedo of the underlying surface. Many studies have identified the possible significance of large-scale land cover change in maintaining the Sahel's catastrophic 30-year drought. Similar discoveries are being made on the potential effects of large-scale changes in the boreal forest region caused by climate change-induced disturbances such as wildfires.

Anthropogenic emissions are already affecting the climate, according to current research (IPCC 2001b). The planet is 0.6o C warmer than it was around 150 years ago, and measurements suggest that this trend is continuing, with 1998 being the warmest year on record. The rise in global mean temperatures has been proven to be responsible for the rise in climatic extremes since the mid-1970s. There has been a rise in drought-affected areas, such as the Sahel, eastern Asia, and southern Africa, as well as incidences of both drought and wet periods in the United States and Europe. This has been connected to the observed change in ENSO activity towards more warm phases after the 1970s, when compared to the period from 1900, which coincided with high world mean temperatures. As climatic variability increases, so do fire-weather risk circumstances and land degradation.

Increasing fire activity in recent decades has been attributed to an increase in fire-weather danger caused by the El Nio-Southern Oscillation phenomena. For example, the destructive "Ash Wednesday" fires in Australia in 1983 left large areas covered in smoke for weeks; and the 1982-1983 and 1997-1998 peat and forest fires in Indonesian and Malaysian provinces estimated to have caused $14 billion in damages to livelihood systems. Warming has been connected to an increase in summer dryness and enhanced evapotranspiration in the high and mid-latitudes, which is associated with a rise in the frequency of exceptional fire years over the circumboreal area (North America and Russia).

In a CO_2 doubling scenario, probable fire weather in the boreal forest extends the fire season by 30 days across Canada. The heightened fire-weather danger is caused by high surface temperatures, which cause more thunderstorms, boosting lightning ignitions by 20 to 40% between 50 and 60° N latitude. Due of rising fire weather severity, human ignition is anticipated to rise by 18 and 50% in Ontario by 2050 and 2100, respectively (Soja et al. 2007). It has been demonstrated in Australia that the frequency of days with extremely high and extreme Forest Fire Risk Index ratings is predicted to increase by 4-25% by 2020 and 15-70% by 2050 in south-east Australia (Hennessy et al. 2006). New Zealand has reached similar findings (Pearce et al. 2005). Forest fires will have a significant impact on future climatic processes as well as land degradation trends. Yet, there have been little research on future changes in fire patterns over most of the developing world, particularly in fire-prone areas like Sub-Saharan Africa, which has extremely fragile economies.

Climatic extremes, such as excessively wet circumstances with increased CO_2, are anticipated to increase the possibility for alien species to proliferate by outcompeting indigenous ones. Studies reveal that a variety of invasive species respond well to rising CO2 levels in the atmosphere under most circumstances, while further research is needed. Experiments in the United States found that a non-native invasive grass called Bromus (cheatgrass), which is known to shift the frequency of intense fires from a 75-100-year cycle to a 4-7-year cycle, was far more productive than native plants during wet years with high CO2 levels. CO2 rise due to climate change is also expected to increase shrub cover. Bond et al. (2003) connected the expansion of shrubs in Southern Africa to the century-long increase in CO2. There are indications that there may be an increased likelihood of large highly flammable biomass accumulation in areas that normally support lower fuel load, resulting in high fire-weather risk, which will have an impact on wild-life and soil.

According to recent studies, the global land area in drought by the 2090s will increase from 1% today to 30%, 40%, and 50% for extreme, severe, and moderate drought, respectively (Burke et al. 2006). Over southern Africa, a 1.5% annual decrease in rainfall has been observed over the last quarter of the twentieth century, accounting for the frequent droughts and subsequent land degradation. Decline during the last few decades' dryness and wetting cycles enhance the risk of wildfires. Increasing fire activity as a result of climate change will significantly diminish plant biomass, and given the likelihood of increased climate variability, these conditions would dramatically increase sensitivity to land degradation. This will have long-term ramifications for soil production, particularly in dry places where soils take longer to grow, such as in arid southern Utah.

Fire forecasting for land degradation reduction

Future land degradation initiatives should include fire pattern monitoring at all levels in order to identify changes in fire type, behaviour, and regimes in response to changes in influential climatic factors caused by global warming. Vast regions of the developing world are already vulnerable to fire for a variety of reasons, including widespread poverty, which necessitates the use of fire as a land use tool, and insufficient resources to monitor and prevent harmful fires. In contrast, billions of dollars are spent annually in the industrialised world to minimise bush fires, for example, $1.6 billion was spent in 2000 fires alone in the United States (Williams 2001). Recent large-scale hot fires caused by global warming, as well as model work indicating that severe fire weather events will become more common in the future, point to the possibility of fire posing a problem of magnitude beyond the capacity of a single nation to handle, regardless of its economic position. The consequences of these fires extend beyond the regions burned and are yet poorly understood. There is also a lack of effort, particularly in the developing world, to determine the yearly area burnt and identify regions at risk of excessive burning. Nonetheless, several satellite products for mapping burned regions have become more widely available.

International fire frameworks must be in place to monitor fire weather in many countries and offer timely information on the scope of the problem, its relationship with land degradation development, feedback on global warming, and consequences for livelihoods. At the 3rd International Wildland Fire Conference and Fire Summit in Sydney in 2003, initiatives to improve worldwide collaboration on wildland fire management were launched. This and other comparable efforts must get to the implementation stage. International fire monitoring should be included in fire early warning systems and connected to land degradation research. This may be developed on top of the fire hazard rating systems, which are rapidly evolving to include satellite-based data. Satellites offer rapid, repeatable, and worldwide coverage of the numerous metrics needed to research fires and land degradation. The normalised difference vegetation Index (NDVI) for assessing fuel load and the MODIS Fire Rapid Reaction Data System for delivering immediate information on current fires are two examples of accessible satellite fire products.

The fire hazard rating system, which requires Meteorological Services to provide fire weather information, is also less common in developing nations. These shortcomings are being addressed via regional and international initiatives. The Global Fire Monitoring Center (GFMC) offers global fire data. The Global Observation of Forest Cover and Global Observation of Land Cover Dynamics (GOFC-GOLD) initiative, among other things, has established a series of regional networks in Southern and Central Africa, Northern Eurasia, Latin America, South East Asia, and Australia to address global land cover and fire dynamics. For example, the Southern Africa Fire Network (SAFNet), a GOFC-GOLD regional network in Southern Africa, has been operational since 2000, concentrating on the use of satellite data in fire management and monitoring these structures serve as rudimentary foundations for constructing a worldwide fire early warning system.

Drought is a natural occurrence, but it is also one of the most prevalent and devastating natural disasters. It is caused by a deficit over a long period of time, generally a season or more. Droughts inflict more economic damage than other natural disasters such as earthquakes and volcanic eruptions in most parts of the world. Global population expansion has raised the demand for water resources and the susceptibility to drought.

Extended drought cycles are a key contributor to land degradation processes, affecting large geographical regions. While such a natural hazard can occur in any climate, it is more common in dry and semiarid environments. Total economic damage from natural disasters climbed from $5 billion per year in the 1960s to more than $50 billion per year in the last decade of the twentieth century (Droughts are among the most costly natural catastrophes, with the 1988 drought in the United States being the most expensive natural disaster in US history prior to the Katrina disaster

"When God created the American West, he supplied plenty of whisky to drink and just enough water to fight over," according to a quote in TIME magazine (1988) on the impacts of the drought, recalling that water scarcity was a big issue more than a century ago in the US west. Water disputes have become even more dramatic in modern society. Droughts have been known since the dawn of time:

Natural disasters are distinguished by the following characteristics:

1. They are triggered by natural processes that can be expedited or exacerbated by human activity, such as big floods or landslides.
2. High magnitudes, having magnitude scales
3. They occur unexpectedly, generally for a short period of time, and are unpredictable in some situations, such as earthquakes, or with little warning time, such as volcanic eruptions.
4. Droughts are an anomaly and are long-lasting phenomena.
5. They cause significant human and economic costs.

Natural drought is a common problem in the Middle East (Bruins 2000). The region's freshwater resources are quite limited in compared to the global average, and water stress is an issue if a country possesses less than 1700 m3 person-1 yr-1. Israel's resources are significantly lower than those of most of its neighbours Water withdrawal outnumbers renewable water resources by 110%.

In order to give information to the public and decision makers, the research outlines the drought consequences in Israel and other semi-arid nations in connection to land degradation and water resource management, and analyses the potential implications for Israel's water resources. The public, and occasionally decision makers as well, do not have long memory, hence it is necessary to present scientific background and information on the drought situation.

Changes in land use, water pumping, and flow diversion have increased the detrimental impact of droughts and resulted in land degradation, such as the drying of wetlands and salinity of freshwater aquifers. Another driver of soil deterioration is the rising use of urban treated waste water for irrigation, which has a substantially greater salt concentration and has a severe economic impact on irrigated agricultural operations. Wetlands and aquatic ecosystems around Lake Kinneret and other parts of the nation were almost dry for six years in a row, impacting fish reproduction and indigenous aquatic species.

Lake Kinneret (Lake of Galilee) is Israel's biggest surface water reservoir, accounting for 30% of total national water usage. Drip irrigation, wastewater recycling, decreased allocations and higher price of water supply, desalinization facilities, and other measures have been implemented. Unfortunately, successive administrations' inability to implement drought contingency planning and sustainable water resource management has already harmed agricultural and environment conservation. Drought is threatening to cause a significant catastrophe in the country's water supplies, affecting all sectors of society.

To deal with future drought periods, a stable water reserve in aquifers and surface water reservoirs is required. Now, the statistics are near to the red line, and a fundamental requirement is for around two billion m3. There is apprehension about the future. The most trustworthy data are rising population and living standards, which indicates a rise in water consumption. In Israel, two primary water programmes are specified. The first is the megaprojects, which include imports from foreign sources through ship or pipe transit, the Mediterranean or Red Sea canal to the Dead Sea. The majority of the projects are no longer viable due to current political concerns. The second approach is based on local development, such as desalination from the Mediterranean, desalinization of subsurface brackish water, increased purification of residential sewage water for agricultural uses, aggressive water-saving policies, and cloud seeding to boost precipitation.

Drought episodes in nations of the Mediterranean and South America

Several Mediterranean nations had seen a rise in drought seasons as well. Morocco has experienced alternating periods of rain and drought since the early twentieth century. This equilibrium appears to have been shattered after 1975, when the number of dry years began to outnumber the number of humid years. Morocco's drought from 1980 to 1984 was possibly the worst in the country's 1000-year history. A significant rate of tree death was observed. In Algeria, the frequency of years with severe drought is 10% near the coast and 20% in the interior. The 110-year-old Tunis-Manoubia station documented 11 drought episodes lasting more than a year. Drought in North Africa creates significant limits that can be disastrous. It has an impact on the entire economy, resulting in a shortfall in meadow herb growth, reduced aquifer replenishment, and increased land degradation processes due to overgrazing and water salinity.

Drought in South America is linked to El Nio years. The Northwest region of Brazil is the most impacted, totaling 800,000 km2. Drought impacted 25 years from 1877 to 1995, and three lengthy droughts of three consecutive years were recorded. The result was a significant fall in vegetation, which caused starvation and high mortality. Agriculture and the environment can be regarded as either antagonistic (win-lose) or synergistic (win-win) (win-win). When agricultural operations, such as clearing forest for agriculture, cause environmental deterioration, or when environmental conservation hinders agricultural activity, a win-lose situation occurs. A synergistic approach, on the reverse hand, presumes that sustainable environmental management and agricultural output can coexist. The Global Environment Facility (GEF) and UNEP have a fundamental objective of mainstreaming sustainable land management into sectors such as agriculture and forestry, assuming that win-win circumstances are attainable. The many conceptual frameworks used and created by UNEP in its GEF-funded land degradation programmes highlight various elements of the interaction between agriculture and the environment.

The report is based on UNEP/GEF experience with the environment-agriculture nexus, beginning with the People, Land Management, and Environmental Change Project (PLEC). By establishing sustainable and participatory methods to biodiversity management and conservation based on farmers' technology and knowledge within agricultural systems, PLEC demonstrates the potential for synergies between environmental and developmental objectives. The Land Use Change, Impacts, and Dynamics Project (LUCID) created a model for assessing biodiversity loss and land degradation across landscapes by combining land use change analyses with social and economic factors. The assessment framework for the Millennium Ecosystem Assessment (MA) provides a platform for decision-makers to: (1) identify solutions that can better accomplish basic human development and sustainability goals; and (2) better comprehend the trade-offs inherent in environmental decisions. In order to analyse the environment-agriculture nexus in drylands, the Land Degradation Assessment in Drylands (LADA) use the Driving Forces-Pressures-State-Impact-Responses (DPSIR) paradigm.

This overview demonstrates how the link between agriculture and the environment may be examined using various models and methodologies based on scale and degree of investigation. At the local level, the PLEC model can help to reconcile environmental and livelihood goals. Land use change analysis is a valuable method for analysing causes of land degradation and biodiversity loss at the landscape level. The MA's ecosystem services approach provides a tool for national decision-makers to make educated choices concerning trade-offs between agriculture/human well-being and the environment. Lastly, LADA will leverage the DPSIR architecture to integrate data acquired at various sizes, from local to global.

Land degradation is a global issue that is linked to desertification, biological diversity loss, and deforestation in arid, semi-arid, and dry sub-humid zones. Desertification is described as land deterioration in drylands, which encompass around 47 percent of the earth's surface (UNEP 1997). Many observers, however, believe that land degradation is highly variable and discontinuous, resulting from various causes and affecting people differently depending on their economic, social, and political circumstances. Estimates of the extent and impact of land degradation are conflicting and have been shown in an increasing number of cases to be based on false assumptions, as in the case of forest islands in West Africa's Guinean zone and soil erosion in East Africa. Because of this complication, various players have pushed for reorienting the United Nations Convention to Combat Desertification (UNCCD) from combating environmental concerns in drylands to improving people's livelihoods in drylands.

It has been argued that the United Nations Environment Program (UNEP) has perpetuated the desertification narrative by playing a key role in organising the United Nations Conference on Desertification in Nairobi in 1977 and its subsequent implementation of the Plan of Action to Combat Desertification. The Action Plan culminated in the report of the Executive Director to the UNEP Governing Council in 1984, which said that "The scope and severity of the problem of desertification as presented to the Desertification Conference and addressed by the Plan of Action have been affirmed. Desertification threatens 35% of the world's land surface and 20% of its inhabitants". In the twenty-first century, UNEP has embraced new scientific data and knowledge of the environment in drylands, and in 2005, it funded the publication of a special issue of the Journal of Arid Environments on the "greening" of the Sahel (e.g. Herrmann and Hutchinson 2005). UNEP has also established a new Land Use Management and Soil Conservation Strategy (UNEP 2004), which emphasises the need of using an ecosystem approach to manage land, water, and life resources.

As a result, a clear relationship is established between environmental, land, and soil concerns, as well as sustainable development and poverty reduction. Human-environment interactions are complicated, influenced by land use and land-use change, climatic variability, and policy and institutional variables. The purpose of this study is to shed light on these connections by reviewing the conceptual approaches and outcomes of various UNEP initiatives co-funded by the Global Environment Facility (GEF). The first section of this study investigates the potential relationships between agriculture and the environment in terms of conflicts or synergies. A thorough grasp of this nexus is required for sound decision-making on appropriate measures to support sustainable development. As a result, the second section provides four distinct frameworks for investigating the agriculture-environment nexus, as created and applied by UNEP initiatives. These frameworks emphasise several competing and synergistic elements of agriculture's interaction with the environment.

Conflicts and synergies between agriculture and the environment

Land degradation is caused by either man-made or natural processes that impair land's ability to operate efficiently within an ecosystem. While investigating the role of land degradation in the agriculture-environment nexus, it is critical to comprehend the human-caused influence on the land's productive potential. The link between agriculture and the environment, on the other hand, is significantly more complicated than simply believing that agriculture causes land degradation. The causal link between agriculture and land degradation also goes the other way, since land deterioration substantially limits agricultural output, as evidenced by economic value of productivity loss owing to soil erosion in East Africa. Views on the interaction between agriculture and environment can essentially be categorised in two, the 'Malthusian camp' vs the 'Boserup camp'. Humans, population expansion, agricultural operations, and the environment, according to the former side, are at odds. They emphasise agriculture's intrinsic degenerative influence on the ecosystem. Fast population expansion is thought to be connected with greater poverty and natural resource degradation, as a result of factors such as land scarcity, shortened fallow times, deforestation, marginal land farming, and underdeveloped human capital.

Agriculture and the environment appear to be at odds in at least two ways: (1) Agricultural operations can degrade the ecosystem. Examples include overgrazing of rangelands, cultivation of land unsuitable for agriculture, or the employment of ineffective land management practises that result in soil erosion, salinisation and water logging, soil nutrient depletion, soil compaction, and so on. (2) Another clashing aspect of agriculture and the environment is when environmental protection hinders agricultural activities, such as in protected areas where cultivation is forbidden.

The second point of view on the agriculture-environment nexus holds that environmental conservation and agricultural activity may coexist. Such a synergistic approach is thus consistent with the 'Boserup camp,' which views population expansion as a catalyst for technical innovation that boosts output. The objective of creating synergies is evident in UNEP (2004) operations and the Global Environment Facility (GEF) - the funding mechanism of Multilateral Environmental Agreements (MEAs) in areas such as biodiversity, desertification, and climate change. Both institutions back attempts to maintain.

Integrate sustainable environmental management with industries like agriculture and forestry. The concept of human-induced desert is connected to the conflict perspective on agriculture and the environment. Its origins may be traced back to French colonial administrators in West Africa, who believed that the Sahara desert was expanding due to unsustainable land management practises such as widespread use of fire for vegetation removal and overgrazing. Swift (1996) contends that the accepted story of desertification served as a handy point of convergence for the interests of three key constituencies: African state governments, international assistance bureaucracies, particularly United Nations organisations, and certain significant bilateral donors. Because of this narrative's prevalence, tactics were adopted that actually worsened the conflict between agriculture and the environment. This was the case, for example, with the agrarian reforms implemented in Ethiopia in the mid-1970s, which reduced farmers' incentives for prudent natural-resource management by reducing both land tenure security and agricultural profitability (Hoben 1996). According to Hoben (1996), the denigration of indigenous agriculture in the neo-Malthusian narrative has led specialists and planners to miss and filter out considerable knowledge concerning the merits of indigenous resource-management methods. The worst aspect of this story, he argues, is that it encouraged significant investment in technology and activities that did nothing to address environmental deterioration or farmer needs.

Long-term research on environmental and agricultural change in the Sahel region of West Africa, many of which are gathered by Leach and Mearns, have called into question well-known desertification narratives (1996a). These research, as summarised by Hutchinson and Herrmann (2005), have shown evidence of major changes from degraded land-use trajectories to more sustainable and productive agriculture systems. Increased grain yields, higher tree densities, improved soil fertility management, locally higher groundwater tables, decreases in rural poverty, and less out-migration are among them. As a result, many local or indigenous land management practises capitalise on the complexity of their operating environments to develop diverse and ecologically resilient land management systems adapted to variability and non-linear processes (Beinart 1996), whereas commercial and intensive agriculture seeks order and uniformity.

Land deterioration can result in three types of difficulties: Land degradation may diminish production at the field level; it can generate problems such as floods and sedimentation at the national level; and it can contribute to climate change and harm to biodiversity and international waterways at the global level. Consequently, land degradation is a source of worry for everyone, even if the effects vary at various sizes. The next sections will present several frameworks for understanding the agriculture-environment nexus at these many levels, with a particular emphasis on the impact of land degradation. These frameworks are thus a suitable starting point for assessing the various parts of the nexus to determine where conflicts need to be resolved and where synergies may be used. The division of levels for interventions is required for suitable ways to be applied and to avoid prior errors in which there was a supposed conflict, but the interventions generated a conflict.

From 1998 to 2002, the People, Land Management, and Environmental Change Project (PLEC) was a global initiative co-funded by the GEF through UNEP and directed by the United Nations University. The primary goal was to create long-term, participatory methods to biodiversity management and conservation based on farmers' technology and knowledge within agricultural systems at the community and landscape levels.

The PLEC investigated the effects of population growth and development on agricultural land resources and biodiversity. It focused on small farmers in the tropics and subtropics, their own inventions and adaptation, and why some manage their resources sustainably while others do not. "The crucial question now is not which traditional traditions, as done in the past, are sustainable, but rather which conditions cause people to conserve their resources, and which situations favour their destruction, or over-exploitation, of local resources," said one of its members. As a result, PLEC hypothesised that in the link between agriculture and the environment, both conflicts and synergies may occur. PLEC set out to uncover elements that predict when conflicts will arise and when synergies may develop using a bottom-up approach using farmers as the entry point. PLEC began as a research initiative concentrating on approaches of farmer resource management, particularly biodiversity resources. The investigation quickly demonstrated that a small group of farmers managed their resources better than others, resulting in higher output while also maintaining or generating biodiversity and lowering environmental damage. These farmers were referred to as "expert farmers" by PLEC.

PLEC established a reproducible technique based on the experience of these expert farmers to allow locally tailored solutions to biodiversity and land management to emerge and be adopted by scientists and policymakers. The idea of agrodiversity, which is a broader word than the more often used concept of agrobiodiversity, was fundamental to this effort. While the latter refers to the diversity of plants and animals used for food and agriculture, agrodiversity is a broader concept that encompasses the interconnections between the natural and modified environment and agricultural activities commonly found in small-scale farming systems in developing countries. It is also linked to challenges of development such as demographics, macroeconomics, and livelihoods. Farmers that use traditional and low-input farming techniques have traditionally favoured farm diversification. Farmers spread risk by preserving diversity and employing a number of tactics. Pretty for example, refers to surveys of non-irrigated rice systems in South East Asia in which farmers described various combinations of landscape position, soil type, hydrology, and flood and drought risk, and demonstrated how they matched these to various combinations of rice varieties and management practises. PLEC developed many agrodiversity factors that conceptually represent not just the diversity in the farmers' fields, but also how they organise themselves and use that diversity.

Agrodiversity is made up of the following components, according to Brookfield and Stocking: Agrobiodiversity refers to the variety of beneficial plants found in controlled environments. It refers to all crops and other plants that are consumed or utilised by humans. Management variety refers to all strategies of managing land, water, and biota for agricultural production and soil fertility and structure. The cornerstone of management diversity is local knowledge that is continually changed by fresh information. Organizational variety is sometimes referred to as the socioeconomic elements of agriculture, and it involves differences in how farms are owned and run, as well as differences in how resource endowments and farm labour are used. Factors include labour, household size, household resource endowments, and reliance on off-farm work. Age and gender relations in agricultural work are also discussed, as are inequalities in land availability among farmers. Hence, organisational diversity encompasses all resource management, including land, crops, labour, capital, and all other inputs. Farmers with varying resource endowments organise differently based on their individual conditions.

These three elements are all part of a transformed environment. Biophysical diversity is a component of the natural environment that relates to soil features and attributes, as well as the richness of natural plant life and faunal and microbial biota. It considers both physical and chemical elements of soil, as well as surface and near-surface physical and biological processes, as well as hydrology.

Variability in climate

Natural environmental elements that influence farm management results include and change, including macroclimate and microclimate. Agrodiversity is the total of all these factors and may be described as "the dynamic variety in cropping systems, outputs and management practise that occurs within and across agroecosystems. It results from biophysical variances, as well as the numerous and changing methods in which farmers manage varied genetic resources and natural variability, as well as organise their management in dynamic social and economic contexts".

The PLEC agrodiversity framework is similar to the more well-known Sustainable Rural Life (SRL) approach created in the late 1990s. "A livelihood involves the capabilities, assets (including both material and social resources), and activities necessary for a means of life," writes Carney. A livelihood is sustainable when it can cope with and recover from stresses and shocks and retain or expand its capabilities and assets both now and in the future, while not compromising the natural resource base". The examination of five different categories of assets from which individuals draw to establish their livelihood is central to SRL. These are assets that are natural, social, human, physical, and financial in nature. To address the question of how farmers use and protect biodiversity, PLEC used an SRL strategy. The terms agrobiodiversity and biophysical diversity in the PLEC framework are similar to the SRL framework's phrase natural capital.

The SRL method is important because it draws attention to the linkages between assets and the alternatives individuals have in practise to pursue other occupations that might create the income level necessary for survival (Ellis 2000). This is similar to the PLEC approach to agrodiversity, in which farmers' use of agrobiodiversity resources varies according to diversity in management and organisation, as depicted in the PLEC framework. Stocking (2002) places agrodiversity and land degradation in the context of the debate over sustainable rural livelihoods and the global environmental agenda. He proposes a "win-win" scenario for long-term rural livelihoods, with components involving land degradation and biological variety. Environmental protection is fundamentally part of the global agenda, as stated in two global agreements (the United Nations Convention to Prevent Desertification and the Convention on Biological Diversity). According to stocking (2002), many land users want to safeguard the environment, but only in the context of their primary purpose of preserving output, rather than for environmental conservation in and of itself.

PLEC recognised these connections, and its demonstration sites demonstrated how biodiversity enhancement may be linked with increases in productivity and subsistence. PLEC was organised into five ecosystem clusters, and its project locations in Africa, Asia, and South America were chosen based on the agrodiversity conditions present in those regions. One of the greatest PLEC instances of agricultural and environmental issues comes from China, where an adept farmer transformed a rocky and sloping 0.5 ha area into an agroforest with over 100 species, including lumber, fruit, medicinal plants, and wild species. The agroforest created a consistent and rising revenue and served as a model for other village farmers looking to reforest the higher slope near the state nature reserve and diversify their income sources as well as the environment.

This approach stands in stark contrast to the monoculture of coffee and sugar crops supported by local businesses. Each of the key pillars of agrodiversity contains examples of how agrodiversity might boost resilience in the face of land degradation and climate change. To promote farmer participation in agrodiversity management, it is vital to look for strategies to connect conservation with development. PLEC's synergistic strategy was effective in connecting the local objective of sustainable rural livelihoods with the global agenda of environmental conservation, that is, combatting land degradation and maintaining biodiversity while sustaining livelihoods. A key takeaway from PLEC is that interventions aimed at addressing land degradation in the agriculture-environment nexus at the local level must take into account the variety of local natural resource users.

Additionally, by recognising farmers' abilities and expertise, the potential for synergy grows. LUCID is a framework at the landscape level. The Land Use Change, Impacts, and Dynamics Project (LUCID) illustrates how to investigate the agriculture-environment nexus at the landscape level. For many years, LUCID has been a network of scientists from prominent national and international institutions investigating land-use change in East Africa and its consequences for land degradation, biodiversity, and climate change. LUCID was led by the International Livestock Research Institute and received GEF support from 2001 to 2004 through UNEP (ILRI). The major goal was to analyse new and existing data on the links between biodiversity change processes, land degradation, and land use in order to create a guide on how to utilize land use change analysis to uncover geographical and temporal patterns and connections.

The use of spatial and temporal analysis of land use change over the last 50 years at project sites in Kenya, Tanzania, and Uganda was a key tool for LUCID. East Africa's land usage has altered considerably during the previous half-century. Some of the LUCID patterns point to a contradictory link between agriculture and the environment. The extension of mixed crop-livestock systems into previous pasture and other more natural regions, as well as agricultural intensification, have been two of the most significant shifts. Changes in land use from bush to pasture have reduced soil organic carbon content, soil moisture, pH, bulk density, and nitrogen. Because earlier techniques of maintaining soil productivity, such as shifting cultivation and fallowing, are no longer utilized, the transition from grazing to continuous cropping has a quick impact on soil attributes.

LUCID also discovered an increase in human-wildlife conflict. This involves bodily harm and loss of life, as well as crop damage. Several farmers have reacted by fencing their property. The influence of fence on livestock management and wildlife dispersal will rise as individual tenure increases. LUCID's overall picture shows that tensions between agricultural and environmental interests are on the rise. LUCID created a model for Land Use Change analysis based on multiple case studies conducted in Kenya, Tanzania, and Uganda. According to this model of land-use change, in pastoral regions without agriculture, the sequence of land cover as a result of land-use change is as follows: woods are turned to bush land, which next becomes grassland, which is now used for cattle grazing.

LUCID devised a more sophisticated series of land-use changes in wetter, agricultural areas. As a result of the transition from forest to grassland, land use shifts from grazing to farming. The land can be used intensively in a variety of ways, including high-intensity grazing, intense monocropping, and intensive mixed cropping. Different land uses have various environmental effects. Nevertheless, extensive land use has a detrimental impact on the environment, resulting in degraded ecosystems (e.g., lower species numbers and plant cover), eroded soils, depleted soil nutrients, native species extinction, and poor agricultural yield.

The LUCID framework incorporates data and theory from ecology, socioeconomics, and land use. In summary, the main results of LUCID include the increase of farming, grazing, and towns at the expense of native vegetation during the previous 20 years, as well as the loss of biodiversity and plant cover that comes with the loss of native vegetation. tive vegetation as a result of farming and overgrazing, resulting in habitat degradation, with severe effects for big species and local extinction. Moreover, the considerable changes in land cover detected by LUCID across wide regions may have negative feedback effects on local and regional climate. Although LUCID did not explicitly examine the links between land-use change, land degradation, and climate change, the project discovered that there was widespread concern about climate change in the region, as well as a perception that extreme weather events such as droughts and floods were becoming more common. As a result, the group concluded that more research on regional climate change trends and interactions between climate change and land cover and land-use change is required.

CHAPTER 11

MILLENNIUM ECOSYSTEM ASSESSMENT (MEA)

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The Millennium Ecosystem Assessment (MA) was a global effort with several partners that was co-funded by the GEF via UNEP. The major goal was to contribute to better decision-making regarding ecosystem management and human well-being, as well as to increase capacity for such scientific evaluations. The evaluation focused on ecosystem services, which are the advantages people receive from ecosystems such as food, water, and climate control, how these services have influenced human well-being, and how such changes may affect people in the future. It also focused on potential solutions at the local, national, and global levels to improve ecosystem management, contribute to human well-being, and reduce poverty.

The MA's Ecosystem Services Approach, which bridges environmental and human well-being issues, is therefore a good framework for examining the links between people and their environment. Land use patterns and practises were highlighted by the MA as one of the key drivers of desertification (MA 2005). Irrigation, for example, has enhanced agricultural and food production in drylands, but in many cases this is unsustainable without significant public capital expenditure. When considering how future development trajectories may effect desertification, the MA believes that population growth and rising food consumption will promote the extension and intensification of cultivated fields (MA 2005). It contends that if left unchecked, desertification and deterioration of dryland ecosystem services would jeopardise future increases in human well-being and may even reverse gains in some locations.

The Assessment is working with many types of ecosystem services (MA 2003): Provisioning Services, which include food, fresh water, fuel wood, fibre, biochemicals, and genetic resources derived from the ecosystem. The advantages received through the regulation of ecological processes such as climate regulation, disease regulation, water regulation, water purification, and pollination are referred to as Regulating Services.

Land Degradation's Impact on Agriculture and the Environment

Cultural Services are non-material benefits obtained from ecosystems, such as spiritual and eligious benefits, educational benefits, or cultural heritage. Supporting Services are services required for the production of all other ecosystem services, such as soil formation, nutrient cycling, and primary production. Changes in these services are influenced by both direct and indirect influences, and these changes have an impact on human well-being. Changes in demographics, economics, socio-political backdrop, science and technology, as well as culture and religion, all influence the direct drivers of change and have an impact on human well-being. Changes in local land use and cover, species introduction or removal, and climate change can all be direct causes of change in ecosystem services. Furthermore, the direct causes of change have an impact on human well-being. Human well-being and poverty reduction are measured in terms of fundamental necessities for living, health, social relationships, security, and freedom of choice and action. The degree of human well-being influences the indirect drivers of change, but it is also influenced by the other three components in this model.

How might the ecosystem services approach help us better comprehend the agriculture-environment nexus? Agriculture might also be viewed as part of human well-being because it supplies fundamental material for a decent living, which is heavily impacted by ecosystem services. The extent to which harvests will be excellent is determined by water, climate, and nitrogen cycling.

As a result, the MA evaluation framework provides a tool for decision-makers to discover solutions for improving basic human development and sustainability goals. All policymakers must strike a balance between economic expansion and social development and the need for environmental protection. In circumstances of conflict between agriculture and the environment, this framework can help with the examination of the repercussions of alternative options, so that agricultural growth does not proceed haphazardly at the national level, as LUCID has observed in East Africa over the previous 50 years.

The assessment approach can also assist decision-makers in better understanding the trade-offs involved in environmental decisions. Progress towards boosting food production, for example, has frequently come at the expense of other goals such as protecting biological variety or improving water quality. The MA supplements sectoral evaluations by providing information on the overall effect of prospective policy options across sectors and stakeholders. A country can enhance its food supply by converting a forest to farmland, but doing so reduces the supply of services that are as or more important, such as clean water, timber, tourist destinations, or flood and drought management. Human actions such as overgrazing and soil salinazation, as well as climatic factors such as inter-annual variability in rainfall and drought events, have a difficult time distinguishing their effects on vegetation production. As a result, the MA proposes that long-term monitoring be conducted to discern between the effect of human actions and climatic variability in vegetation productivity.

Evaluation of Land Degradation in Drylands

The Land Degradation Assessment in Drylands (LADA) expands on the MA's suggestions for fresh, trustworthy data on the extent and consequences of desertification (MA 2005). LADA is an ongoing initiative that receives GEF money through UNEP from 2006 to 2010 and is led by the United Nations Food and Agricultural Organization (FAO). LADA's major goal is to examine the causes, state, and effect of land degradation in drylands in order to enhance decision making for sustainable dryland development at the local, national, sub-regional, and global levels. LADA will perform a worldwide assessment of the prevalence and scale of land degradation using remote sensing and climatic data to create maps of changes in Normalised Difference Vegetation Index (NDVI) and rain-use efficiency over the last 20 years. It will also collaborate with six pilot nations to create national-level evaluation tools and techniques. South Africa, Senegal, and Tunisia are in Africa, Argentina and Cuba are in Latin America and the Caribbean, while China is in Asia. Furthermore, a number of additional nations and areas.

Central Asia, for example, has indicated interest in the LADA technique. Assessments are aimed to guarantee that the benefits of capacity building and decreased land degradation achieved at the national or regional level are transferred to the local level where deteriorating land use activities and the costs of land degradation are incurred. LADA will employ the Driving-Force, Pressure, State, Impact, and Reaction (DPSIR) framework, which is currently widely used in organisations such as the EU and the UN. The DPSIR framework will be utilised for data integration at all levels, from local to global. Nevertheless, one of the framework's shortcomings is that it does not take into account interactions between factors in each box, hence LADA will attempt to discover aggregated indications.

The various theoretical frameworks addressed in this paper contribute to a better understanding of the agriculture-environment nexus in various ways, and our examples demonstrate that different scales of investigation necessitate different models and methodologies. Locally, it is critical to discover synergistic conditions and tactics that improve rural lives while also safeguarding the environment. The PLEC Agrodiversity technique is an excellent tool for undertaking this sort of study. It is a modification of the more widely recognised Sustainable Rural Life framework, which is frequently utilised in development circles.

An essential purpose of the analysis at the national and regional levels is to detect long-term patterns and whether there are conflicts between agricultural expansion and environmental sustainability. If this data is utilised to influence policy and planning, scenarios like the one outlined by LUCID in East Africa, where escalating conflicts between different forms of land use jeopardise the region's long-term environmental sustainability, and may be averted. The LUCID framework includes a tool for this type of study.

Integration of information at multiple sizes and across sectors is required to acquire a global perspective of environmental changes caused by agriculture, and both the MA and DPSIR frameworks can be employed depending on the nature of the data and the target audience. The MA framework may also be utilised at the national level to examine trade-offs between various land-use scenarios. It is also vital to assess the potential value of all ecosystem services in this context. Previously, decision-makers mainly considered the more evident provisioning functions of ecosystems, such as food and fuel production. Yet, for long-term sustainable natural resource management, trade-offs between provisioning services on the one hand and regulating, supporting, and cultural functions of ecosystems on the other should be addressed before choices affecting the agricultural and environment nexus are made.

Because these frameworks are scale sensitive, they can help to build more efficient and effective policies and programmes to combat land degradation. As a result, they serve as a tool for decision-makers and players involved in development interventions aimed at the agriculture-environment nexus to build locally adopted solutions that spark synergies and avoid conflicts.

In order to grasp the function of climate in understanding the agriculture-environment nexus, long-term patterns in climate and land-cover change must be understood, as well as how they interact. The LUCID project, as well as long-term studies of rainfall and land cover changes in the Sahel, demonstrate this the 'greening' of the Sahel is mostly due to increasing rainfall from 1980 to the present. Furthermore, different forms of land use have varying potentials for storing carbon below and above ground, but new methods for estimating carbon stocks are needed to improve our knowledge of how climate, agriculture, and the environment interact (e.g. Milne et al. this issue). Linkage of climatic data with long-term trends in land-cover change is thus required in order The Role of Land Degradation in Agriculture and the Environment Nexus 281 understands the change drivers at the agriculture-environment nexus, a component that requires further development in the frameworks examined in this research.

Landslides are important natural dangers that reduce soil production, hurt persons, and cause property damage. The most prevalent cause of landslides globally is prolonged and severe rainfall. During rainy antecedent circumstances, sites are most vulnerable to landslides. Deep-seated, slow-moving landslides (e.g., earthflows, slumps) are typically caused or reactivated by a buildup of precipitation over several days or weeks. Shallow, quick landslides (debris avalanches, debris flows) on the other hand, typically begin after particular violent or big storm episodes. The capacity to correlate meteorological conditions with diverse types and extents of slope collapses is critical to successfully anticipating landslide dangers across wide areas. The following strategies are addressed for relating existing meteorological and climate information to landslide initiation: (1) basic rainfall-landslide connections; (2) multi-factor empirical evaluation methods; (3) distributed, physically-based models; and (4) real-time warning systems. Each of these strategies has advantages and disadvantages when it comes to assessing landslide hazards. Roads/trails and forest conversion to agriculture (usually linked with burning) are the land use activities that have the greatest influence on landslides. Climate change scenarios that encourage stronger storms, greater rainfall, and plants with poorer root structure or less root biomass are anticipated to enhance landslide vulnerability; however, such implications are presently speculative and will be difficult to distinguish from anthropogenic effects.

Widespread changes in land cover are occurring in developing regions of Africa, Asia, and Latin America as a result of forest conversion to cultivated agriculture, exotic plantations, and pastureland; shifting cultivation; urban and residential sprawl; and networks of poorly designed roads and paths. These land activities increase the likelihood of landslide initiation by lowering soil rooting strength, decreasing evapotranspiration while increasing soil water content, and producing un- 286 On hillslopes, Roy C. Sidle stable cuts and fills (Sidle et al. 2006; Sidle and Ochiai 2006). Unfortunately, the effects of landslides on land degradation are frequently overlooked for two reasons: (1) awareness of landslides is frequently limited to cases where lives are lost and buildings are damaged; and (2) landslides occur episodically, and the long-term significance of these processes is typically overlooked if such failures have not occurred in recent years. Disregard for landslide risk can be inadvertent, as in many rural regions in underdeveloped nations, or 'blindly purposeful,' as in the case of urban developers.

Extended and severe rainfall is the most prevalent cause of landslides. Consequently, landslides vary from many other forms of land degradation processes in that they are more prone to occur in seasonally wet areas. Earthquakes can also cause spectacular landslides, which strike abruptly and can result in significant deaths. Nonetheless, earthquake-caused landslides are far less common than rain-caused slope collapses. Landslides occur in mountainous areas with high snowfall during the melt season, and are occasionally accompanied by rain-on-snow.

Depending on the kind of possible landslide, antecedent soil moisture has a significant impact on the stability of hillslopes during individual rainfall events, protracted series of storms, and earthquakes. Deep-seated, slow-moving landslides (e.g., earthflows, slumps) are typically caused or reactivated by a buildup of precipitation over several days or weeks (Iverson and Major 1987). Shallow, quick landslides (debris slides, debris avalanches, and debris flows), on the other hand, typically occur during particular strong or big storm events, which may be preceded by wet conditions. The capacity to correlate climatic conditions with distinct landslide types, as well as the severity and frequency of these failures, is critical to successfully anticipating landslide dangers across wide regions. This chapter describes four strategies for relating existing meteorological and climatic information to landslide initiation: (1) straightforward rainfall-landslide connections; (2) multi-factor empirical evaluation techniques; (3) distributed, physically based models; and (4) real-time warning systems. Each of these strategies has advantages and disadvantages when it comes to assessing landslide hazards. In addition, several climate change and land degradation scenarios will be examined in relation to these landslide prediction and forecasting methodologies. While the emphasis here will be on land degradation, it is not possible to remove the more catastrophic issue of potential deaths from this topic, particularly for underdeveloped countries.

Rainfall and snowmelt timing (relative to pre-existing climatic conditions) and geographical patterns are strongly linked to landslide initiation. Higher mountain heights typically receive more rain and snow due to orographic influences. Utilizing Meteorological and Climate Information to Landslide Prevention and Mitigation 287 snowfall. Rainfall-initiated landslides may also occur in dry areas as a result of strong precipitation linked with convective storm cells (e.g., Caine 1976; Rapp and Nyberg 1981). The following climate variables have a direct impact on landslide initiation: (1) total storm rainfall; (2) short-term intensity; (3) antecedent storm precipitation and its distribution prior to the landslide-triggering event; (4) storm duration; (5) snow accumulation and water content; and (6) snowmelt rate (associated with radiation and wind). Many of these characteristics have an impact on the development of pore water pressure in unstable hillslopes (Sidle and Swanston 1982; Fernandes et al. 1994). While many studies in mountainous regions have implied a correlation of long-term precipitation with shallow landslide occurrence (e.g., Eyles 1979; Glade 1998; Pasuto and Silvano 1998), other studies where more detailed precipitation data have been collected (e.g., Sidle and Swanston 1982; Keefer et al. 1987; Larsen and Simon 1993; Finlay et al. 1997; Fuchu et al. 1999) have concluded that short-term rainfall intensity is a more important triggering factor. However, in impoverished countries, where the consequences of landslides are the most severe, short-term (hourly) rainfall data is scarce. Thus, while daily rainfall data are useful indicators of landslide risk areas, short-term rainfall intensity data obtained from continuous rainfall records are far more applicable to landslide prediction (e.g., Wu and Sidle, 1995; Baum et al. 2002) and real-time landslide/debris flow warning systems.

Shallow, quick landslides on hillslopes are made up of debris slides, debris avalanches, and debris flows, with the water content and speed of movement rising as the water content and speed of movement increase. Debris flows are also in-channel phenomena that can be directly related (in time) with landslides or can occur independently of landslides as a result of a gradual in-filling of landslide debris and other erosion/bioturbation materials (Trustrum and DeRose 1988; Benda and Dunne 1997; Sidle and Ochiai 2006). A debris slide or avalanche on a hillside may frequently travel fast downslope to a channel, where it will become a debris flow after absorbing more water (Sidle and Chigira 2004; Chen 2006). Such combination slide-flows frequently entrain more materials as they go downslope and can thus be quite lethal

These normally shallow landslides occur on steep slopes with low-cohesion soil mantles, where either the underlying bedrock or another low permeability substrate promotes the accumulation of a perched water table during storms or snowmelt episodes. The most vulnerable slopes in plan form are concave, although these rainfall-initiated landslides can also occur on planar or even convex slopes.

Shallow groundwater collects in the soil mantle above a low permeability layer after heavy rainfall or snowmelt episodes. In rare circumstances, underground water can enter via fissures in the underlying bedrock. Particularly extensively worn or altered clay-rich regoliths subject to plastic deformation under a variety of soil water conditions. To commence slope movement, a prolonged wet or snowmelt period of several weeks or longer is usually necessary. Following then, movement continues through the rainy or melt season before slowing down when water inputs are intermittent. Rotational slumps, earthflows, and slump-earthflow combinations are examples of such landslides. Soil creep, while not a landslide in and of itself, is a plastic deformation of the hillslope soil mantle that acts similarly to earthflows. Although slow, deep-seated mass movements seldom kill individuals, they can cause significant property damage and convey vast amounts of silt to streams and rivers in some areas.

Deep-seated slope collapses typically respond non-linearly to soil water accumulations. During dry seasons, infrequent rainfall events may cause little or no movement. However, once the soil mantle has been recharged to a critical level, mass movement responds to additional rainfall or snowmelt inputs (Swanson and Swanston 1977; Bechini 1993), as demonstrated by an example of earthflow movement and groundwater response for the massive Chausuyama landslide in Nagano Prefecture, Japan. As a result, generalising about threshold triggering climatic conditions is challenging, and it is frequently important to acquire groundwater data in specific movement sites to determine dynamic behaviour. Localized structures such as sag ponds, terraces, and tension fractures on these mass movements store or channel water and intensify episodic movement

Although dry ravel and dry creep are not technically landslides, they do entail the downslope movement of individual soil grains, aggregates, and coarse fragments by gravity and are therefore categorised as mass wasting processes. Dry ravel is frequently visible as talus cones or accumulations at the base of steep, thinly vegetated hillslopes or behind barriers

Soil freezing-thawing and wetting-drying cycles have a significant impact on rake. As a result, ravel responds to quite distinct climatic features than other mass wasting processes. Mean storm strength - duration associations for landslide triggering events have been created for global and regional data sets. When such basic correlations are combined with real-time rainfall data, such studies can serve as the foundation for shallow landslide early warning systems. Caine (1980) discovered a log-log association between average rainfall intensity during storms and storm duration using a worldwide data set of 73 small landslides and rainfall data

The bottom threshold of this connection is provided as: I= 14.82 D-0.39 where I is the mean intensity of the downpour (mm h-1) and Ds is the storm duration (h). Hence, shallow, quick landslides may occur at any time during a storm when the average rainfall intensity reaches the threshold value (I). Several places have seen a more regional use of this mean intensity - duration strategy of creating threshold triggering conditions for shallow landslides. Larsen and Simon (1993) focused on a collection of 256 tropical storms that caused landslides in Puerto Rico during a 32-year period (in contrast to Caine's prior data, which was largely from temperate locations).

As compared to temperate locations, 10 hours of rain intensity was required to initiate landslides in Puerto Rico; after 4 days, the rainfall required to generate landslides converged with Caine's worldwide threshold. Two investigations in Italy produced contradictory findings, indicating the need of careful geographical definition. In Campania, intensity-duration thresholds all projected significantly beyond Caine's global threshold, owing in part to the exclusion of chosen data from smaller events involving just single debris flows in these pyroclastic deposits (Fiorillo and Wilson 2004). The intensity-duration threshold that caught 90% of the landslides from four occurrences in the Piedmont Area of northwest Italy was marginally below Caine's threshold for long-duration storms (> 10 h); for shorter duration storms, the thresholds were identical (Aleotti 2004). Wieczorek (1987) discovered that the intensity-duration threshold in the Santa Cruz Mountains of California, based on 7 years of climatic data in which individual landslides were documented, was significantly below Caine's threshold. Dhakal and Sidle (2004a) modelled the occurrence of shallow landslides during the 86 most significant storms on Vancouver Island, British Columbia, from 1972 to 1990 and compared their characteristics to Caine's global threshold; 65 storms produced only one landslide, and 36 of these storms were below Caine's threshold; all 21 storms that produced two or more landslides were above the threshold. Cannon and Ellen (1985) classified the San Francisco Bay area into low (660 mm) and high (> 660 mm) mean annual precipitation categories.

Utilizing Weather and Climate Information for Landslide Prevention and Mitigation 293 ity and real-time rainfall data to construct a warning system for landslides in the region during large storms. The precipitation requirement is higher than Caine's criterion since these thresholds were developed for plentiful landslides; nevertheless, the dry precipitation threshold is identical. In areas where rainfall intensity-duration-frequency correlations are extensively established, they can be superimposed on mean storm intensity-duration thresholds to determine return periods for specific combinations of precipitation intensity and duration that may cause shallow landslides (Sidle et al.

1985). These threshold relationships are difficult since they are based on landslides produced by low rainfall inputs under almost saturated soil conditions. To effectively exploit such basic intensity-duration correlations for shallow landslide prediction, an indicator of antecedent soil moisture or at least wet and dry antecedent soil moisture conditions may be required. It is evident that daily rainfall measurements will not enough to apply even the most basic correlations between rainfall and landslide incidence. The minimal amount of climatic data necessary must be of sufficient resolution to determine average storm strength and storm duration. In general, this would need hourly rainfall data.

CHAPTER 12

THERMODYNAMIC EQUILIBRIUM

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All a system's attributes have fixed values at a certain state. As a result, the system's state alters if the number of any one attribute does. While a system is in equilibrium, its attributes do not vary in value when it is separated from its environment. We define a system that is in thermal equilibrium when the temperature is constant across the whole system.

a) The system is described as being in mechanical equilibrium if there is no change in the pressure at any point in the system.
b) We refer to a system as being in chemical equilibrium so when chemical composition of the system does not change over time.
c) When the mass of every phase achieves its equilibrium level in a two-phase system, phase equilibrium has occurred.

If a thermodynamic system is in chemical, mechanical, and thermal equilibrium and the pertinent parameters stop changing over time, it is considered to be in thermodynamic equilibrium.

Thermodynamic Properties

The definition of thermodynamic properties is "characteristic aspects of a system, enabling to identify the state of the system." Both widespread and intense thermodynamic properties are possible. Intensive properties are those that are independent of the amount of substance present. Temperature and pressure are powerful elements. Extensive characteristics have values that are dependent on the system's mass. The qualities of volume, energy, and heat are all extensive.

Enthalpy

In a thermodynamic system, energy is measured by enthalpy. Enthalpy is a measure of a system's overall heat content and is equal to the system's internal energy and the total of its volume and pressure. In mathematics, the enthalpy, H, is equal to the combination of the system's pressure, P, its volume, V, as well as the total of its internal energy,

Entropy

The value of entropy, a thermodynamic variable, is dependent on the physical configuration or circumstance of a system. In other terms, it is an enthalpy function that is used to quantify disorder or unpredictability. Entropy of a solid, for instance, where the particles may move freely, is lower than that of a gas, where its particles would fill the container.

Laws of Thermodynamics

Thermodynamic ecosystems at thermal equilibrium are characterized by fundamental physical constants like energy, temperature, and entropy, which are defined by thermodynamic laws. These thermodynamic principles describe how these quantities act in different situations.

Zeroth law of thermodynamics

According to the Zeroth Law of Thermodynamics, when two bodies are in thermal equilibrium with a third body, they are likewise in equilibrium state with each other. This indicates that if system A and system Care in equilibrium temperature with one another and system B and system C are likewise in thermal equilibrium, then systems A and B must also be in thermal equilibrium.

Think about two cups A and B filled with hot water. A thermometer is put in cup A, where the water warms it up until it registers 100 °C. Scientists say that perhaps the temperature is in harmony with cup A when it registers 100 °C. The thermometer continues to indicate 100 °C even after we move it to cup B to check the temperature. Additionally, the thermometer and cup B are in balance. We may infer from the zeroth thermodynamic that cups A and B are in a state of equilibrium with one another.

First Law of Thermodynamics

The first law of thermodynamics may appear abstract, but if we consider a few examples, we will understand it better. Fundamental Thermodynamic Law Examples: Through the process of photosynthesis, plants transform the incident radiation of sunlight into chemical energy. We breathe, swim, walk, and scroll around this page by consuming plants, which then transform their chemical into kinetic energy. Even while turning on a light may appear to create energy, electrical energy is actually transformed.

Second Law of Thermodynamics

According to the second rule of thermodynamics, entropy always rises in an isolated system. Any isolated system will naturally progress towards thermal equilibrium, which is the condition in which the system's entropy is greatest. The unpredictability of the cosmos never diminishes; it only grows. This remark has a significant influence and has consequences that are often overlooked and taken for granted.

Visualizing the second law of thermodynamics

If a space is not kept tidy or clean, it will inevitably get messier and more chaotic over time. The entropy of the room lowers as it is cleaned, but because of the cleaning effort, entropy from outside room has grown, surpassing the entropy that was lost.

Third Law of Thermodynamics

If a space is not kept tidy or clean, it will inevitably get messier and more chaotic over time. The entropy of the room lowers as it is cleaned, but because of the cleaning effort, entropy from outside room has grown, surpassing the entropy that was lost.

Macroscopic Approach and microscopic approaches

Macroscopic Approach

The method assumes that such system is composed of a very big number of distinct molecules. These molecules' energy and velocities vary. These energy' values are continually shifting over time. Statistical thermodynamics is a branch of thermodynamics that directly addresses the form of the matter, because there are a lot of molecules in the system

Statistical approaches are used to determine its behavior. Therefore, sophisticated statistical and mathematical techniques are required to describe the system changes. The characteristics of the molecule, such as velocity, velocity, impulse, kinetic energy, and the inability of sensors to accurately detect forces of impact, etc. It takes a lot of variables to adequately characterize a system. The investigation is conducted in a broad manner using a macroscopic approach. By using this strategy, a system is defined dependent on variables like temperature and pressure. Every molecule there in system is represented by these parameters. With a small set of variables, a macroscopic technique is fairly simple to use. Another name for this strategy is classical thermodynamics

Microscopic Approach

The system is investigated using a microscopic approach by examining each molecule's behaviour. In this instance, we consider the fact that just about every molecular in a complex has a distinct energy and a different amount of excitation. Therefore, statistical analysis is used to predict the behaviour of a system being examined using a microscopic technique. The technique is highly challenging and time-consuming since statistics are employed to locate the answer. These are difficult to assess using individual behaviour variables like momentum, velocity, etc. Another name for this approach is statistical thermodynamics. a specific amount of stuff is taken into consideration despite taking into account molecular level processes. In other words, this method of studying thermodynamics is focused on overall or gross behaviour. Classical thermodynamics is what this entails. Macroscopic system analysis calls for a straightforward mathematical formula.

The average values of the system's characteristics represent their worth. Consider a measurement of oxygen in a small box as an example. The average amount of pressure sent forth by thousands of individual molecules makes up the gas's pressure only a few attributes are required to characterize a system.

Differentiate between Macroscopic and Microscopic Approaches

The use of statistical thermodynamics in the microscopic method is the primary distinction between the macroscopic and microscopic approaches. Macroscopic Approach: The classical theory of thermodynamics employs this method. Each material is made up of many molecules.

The behavior of these molecules affects the substance's qualities. Either a micro (micro means little) or a macroscopic (macroscopic means huge) perspective may be used to examine a system's behavior. Table 14.1 Represents the Difference between Microscopic and Macroscopic Approach.

Table 14.1 Represents the Difference between Microscopic and Macroscopic Approach

Macroscopic	Microscopic
a) In this method, a specific amount of matter is taken into consideration without being considered molecular-level occurrences.	a) The molecules, which are thought to make up the majority of the matter, are thought to move disorderedly and randomly. The impact of molecular mobility is taken into account.
b) The system's entire behaviour is the focus of an analysis.	b) Analyzing the behavior of the system requires understanding the structure of matter.
c) In the study of traditional thermodynamics, this strategy is employed.	c) The study of statistical thermodynamics employs this method.
d) It is simple to measure the system's necessary parameters, such as pressure, temperature, etc.	d) The system's necessary characteristics, such as velocity, inertia, kinetic energy, etc., are difficult to quantify.

Some major difference

1. The microscopic technique uses statistical tools to analyses each molecule's behavior, the macroscopic approach is focused on the overall or average impact of many molecules' violations.
2. In contrast to the microscopic technique, where there are many more molecules than in the macroscopic approach, statistical approaches are used to determine the behavior of the system. As a result, to assess the system changes, both intricate mathematics and statistical techniques are needed.
3. As you describe a system only a few characteristics, such as force, volume, temperature, etc., are necessary when using the macroscopic method. The strategy is straightforward as a result. In contrast, the microscopic technique requires a huge number of variables, which makes the approach difficult.
4. The values of the system's attributes in a macroscopic perspective are their average. Take a sample pf gas in a small box as an example. The average amount of pressure sent forth by thousands of individual molecules makes up the gas's pressure. The qualities that describe a molecule, like as momentum, velocity, kinetic, impulse, and instruments, cannot be measured using a microscopic technique. Since these are actual values, measuring them is challenging.

5. In contrast to the microscopic method, which makes use of the molecular theory of matter, the macroscopic approach makes no assumptions about the structure of matter.

Thermodynamic System

A thermodynamic system is one that is separated from its surroundings by actual or fictitious barriers. The area of the universe where observations are made is referred to as a thermodynamic system, and the area around it is the rest of the universe. Other than the system, everything is in the surroundings. The cosmos is made up of the system and its surrounds. A thermodynamic system interacts with and may exchange heat with its surrounds, or environment, through which it can carry out work. Through a barrier, it transfers heat to its surroundings. The barrier is the physical line dividing the system from its surroundings. In addition to undergoing internal changes, thermodynamic systems can transmit power or matter with their surrounding environment

Classification of Thermodynamic Systems In brief

Closed system

If a system exchanges energy with its environment but its mass doesn't change, it is said to be closed. In other words, while a closed system's volume cannot change, no mass can enter its boundary. An illustration of a closed system is the gases in a conducting piston with a surface piston No mass surpasses the barrier in this situation. The volume of the gas may, however, be altered by the movement of the piston. It's possible that energy may transcend the border due to the conducting nature of the piston and engine blocks. That is, there is an exchange of energies but not of matter in a closed environment (mass).

Open system:

If a system exchanges mass as well as energy with its environment, it is said to be open. The control volume, on the other hand, is a fixed volume in an open system. An everyday illustration of just an open system is a bathroom water heater that is electrically powered. To provide a consistent supply of hot water, the water in its barrel is heated. Cold water enters the tank to replace the hot water that was previously going out. It is not practical in this situation to select a certain mass of water for our system

Classification of Boundaries

Diathermal Boundary

It is Refer to a boundary as being diathermal or thermally conductive if it permits the flow of energy between system and its surroundings. It should be noted that a barrier like that brings the system into thermal contact with its surroundings. Providing a diathermal barrier to its contents is a metallic (tea) pot.

Adiabatic Boundary

A border is referred regarded as being adiabatic if no heat can pass across it. The system is thermally isolated from its surroundings by an adiabatic border. A full thermos flask with a tight-fitting cover is a thermally isolated system because the ideal thermos flask has an adiabatic wall.

Rigid boundary

A border is considered stiff if it can't be moved even by a strong mechanical force from outside. An unmovable barrier prevents the compression or expansion of a system. The closest simulation of a solid border is the surface of a steel ball used in "shot put."

Permeable Boundary

Refer to a border as being permeable if it permits the passage of stuff.

Semi-permeable Boundary

A border is said to as semi-permeable if it allows certain system elements to flow past it in a selected manner. A great example of a semi-permeable border is hot quartz, which only permits helium to go through. Moderately membranes are used in RO water purification systems to screen out contaminants

Reversible and Irreversible Processes

A process is referred to as reversible if it can be reversed through the same equilibrium stages and is carried out in such a gradual, controlled manner that all of the intermediate states here between initial and final stages are in equilibrium. The procedure is referred to as irreversible if the aforementioned requirements are not met.

Quasi-static Processes

A process is considered to be quasi-static if it is carried out in such a way that it goes through states that are not equilibrium states but depart only incredibly from equilibrium states (i.e., almost static). A sequence of equilibrium states are therefore closely approximated by a quasi-static process. The process is not quasi-static unless there are finite deviations from equilibrium.

Think about heating a system from its starting temperature T1 to its desired end temperature T2. This might be accomplished by encircling the system with a diathermal barrier and keeping the area around it at T2. However, because the system's temperature rises more quickly at its border than it does at other points in the interior, this process will not be quasi-static. The temperature of the environment should be retained initially at T1 and subsequently elevated sufficiently slowly such that it is always infinitely small higher than that of the system in order to heat a system quasi-statically.

CHAPTER 13

FIRST LAW OF THERMODYNAMICS

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Internal energy is a state variable found in an equilibrium thermodynamic system (E). The difference between the internal energy of two systems are equivalent to the distinction between the amount of heat that is transferred into and used by the systems. First law of thermodynamics states that the energy of the cosmos is unchanging. It cannot be created or destroyed, but it may be transferred here between system and the environment. The law mainly addresses modifications in energy states brought on by labor and heat transport. The idea of energy saving is rethought. The First Law of Thermodynamics states that heat is a kind of energy; hence, the idea of energy conservation governs thermodynamic processes. Because of this, neither hot nor cold energy may be generated or destroyed. It can, however, be transformed to and from other forms of energy and transferred from one area to another.

$$\Delta U = q + W$$

Where W is the work interaction between the system and its surrounds and U is the change in the the system's internal energy. Q is the sum of energy transfer between the system and surroundings.

1. In an isolated system, energy (E) is consistently constant.
2. A system characteristic and a point function, internal energy. Specific heat capacity is a narrow (widespread) quality, whereas internal energy is a wide (mass-dependent) characteristic (independent of mass).
3. A perfect gas's internal energy is only dependent on temperature.

Significance of First Law of Thermodynamics

Energy conservation is the cornerstone of the fundamental law of thermodynamics. This shows that while energy cannot be created or destroyed, it may change into many states without suffering an energy loss. Both dQ and dW are impacted by the process when a system switches through one state to another. However, dU is constant across all operations.

Limitations of First Law of Thermodynamics

1. The law states that a system always should maintain a perfect energy balance while undergoing a thermodynamic process. From the other hand, the first law does not address whether the system's process or state change is feasible.
2. For instance, the first law does not explain why, when a copper rod is warmed at one end yet not the other, heat travels from the hot side to the cold end and vice versa.
3. Only the quantity of energy transmitted during this operation is measured by the first law. The viability of various processes is measured against the second rule of thermodynamics.

First law of Thermodynamics for a Closed System

The sum of applied pressure and pressure-induced volume change results in work in a closed system.

$$W = -P\,\Delta V$$

Where P denotes the system's constant external pressure and V denotes the system's fluctuating volume. This type of job is known as pressure-volume work.

When work contact happens outside of a system's boundaries, its internal energy either increases or lowers in reaction. When work is done to the system, internal energy rises; when work is done to the system, it falls. The system's internal energy is altered by any thermal exchange that takes place within the unit with its surroundings. The first rule of thermodynamics states that energy is constant, hence the overall energy change is always zero. If the mechanism loses energy, the environment absorbs it. When a system absorbs energy, it signifies that the environment released the energy:

$$\text{System} = -\text{Surroundings}$$

Applications of First Law of Thermodynamics

Isothermal process

In an isothermal operation, an ideal gas's temperature stays constant. This indicates that the system uses the heat it receives to work it against environment. Thus,

$$dQ = dU + dW.$$

$$\Rightarrow dQ = dW$$

Melting process

A solid gains internal energy as it transforms into a liquid. Let L be the solid's latent heat and m be the mass of the liquid. The system's absorption of heat, where $dQ = mL$.

There is a negligible amount of expansion, or $V = 0$.

$$\Rightarrow dW = P\Delta V = 0$$

So,

dU plus dW Equals dQ

$$\Rightarrow dU = L$$

Thus, when the material melts, internal energy rises.

Heat engines

The First Law is most frequently used in practical applications using the heat engine. Heat engines are used to transform thermal energy into mechanical energy and vice versa. Heat engines are almost always open systems. The fundamental concept of a heat engine relies on the relationships between heat, size, and pressures of a working medium.

Preparation of Fruits and Vegetables for Canning

Washing

Fruit and vegetables are typically cleaned with water to remove clinging surface microflora, dust, and other impurities. Fruits like peaches, apricots, and others are lye peeled rather of being washed first. On the contrary hand, bathing after peeling should be avoided since it destroys vitamins and minerals. There are other ways to wash, such as soaking or stirring in water, using hot or cold water sprays, etc.

a) In mechanical washers, the product is tumbled or agitated while submerged in water or exposed to water sprays on rotating screens or moving belts.
b) The best way to wash is using high pressure sprays.
c) The wash or rinsing water commonly contains detergents.
d) To disinfect them, vegetables can be placed in a solution of potassium permanganate or bleach (25–50 ppm).
e) The warmth of the water

Sorting and grading

Sorting and grading make ensuring that poor or damaged goods are removed. Along with educated employees who can spot low quality food unfit for canning, an inspection machine can be employed for sorting.

a) To cut down on labour costs, automatic colored sorters can be utilised for sorting.
b) After initial sorting, the fruits and vegetables are evaluated to achieve uniform quality in terms of size, colour, etc.
c) Grading may be performed manually and with the use of grading equipment.
d) Fruits and vegetables are run across screens containing holes of varying diameters for mechanical grading.
e) Mechanical graders come in a variety of forms, including screen graders, roller graders, rope or cable graders, etc. The most popular type of screen graders are those with vibrating screens made of copper and circular apertures.
f) Fruits with soft skins and berries are often assessed by hand.
g) While peaches, apricots, pears, mangoes, and other fruits are assessed after being cut halves or slices for canning, plums, cherries, and olives are graded whole.

h) On the basis of cap size, white button fungi are rated. Only buttons with a cap diameter of up to 2.5 cm and a small head are given an A grade; caps larger than 2.5 cm are given a B rating.

Peeling, coring and pitting:

These are the main unit procedures for canning fruit and vegetables. The technique of peeling and coring is chosen depending on the kind of commodity, such as:

a) by foot or knife
b) by machinery by heat treatment
c) by employing lye solution. Apple, peach, apricot, and other fruits have their cores and pits removed either by manually or by a machine (de-corer).

Hand peeling:

Using peeling knives, many vegetables and fruits are peeled and sliced by hand. When peeling fruit with uneven shapes, a peeled knife with a curved blade and a specific guard to control peeling depth can be used.

Mechanical peeling

Pears, apples, carrots, turnips, potatoes, and other fruits and vegetables are peeled using mechanical peeling, coring, and cubing equipment. Peaches and cherries are also peeled using automated peelers.

Lye peeling:

With plenty of water and a heat source, lye is a boiling excellent solvent of caustic soda (Sodium hydroxide) or potassium hydroxide (1-2%) that is used for peeling. Peaches, nectarines, apricots, sweet orange segments, carrots, and sweet potatoes are just a few examples of the fruits and vegetables that can be peeled through dipping them in heating caustic soda (1-2%) for 1-20 seconds (depending on the lye concentration, temperature/maturity, and nature of the fruit or vegetable), followed by dipping in water. The meat beneath the peel is separated from the hot lye by a gentle hand-rub of the fruit. To neutralize the alkali, the fruit could also be briefly submerged in a diluted solution of citric acid or hydrochloric acid.

1. Equipment for lye peeling ranges from a basic stainless steel (SS) pan with lye solution with SS baskets acting as cages to a fully mechanized system.
2. The peeling system used in cottage and small-scale canning facilities consists of three stainless steel tanks connected in series, one of which has a steam vent. The second tank has a diluted solution of acid or hydrochloric acid, while the third tank holds tap water.
3. The fruit or vegetables are submerged in the first tank, which contains a boiling, hot lye solution, after being inserted in perforated SS crates, baskets, or cages. The crates are instantly submerged in the second tank to neutralize the lye after the first tank's dipping treatment takes place, and the third tank is used for the final washing.

Cutting halving slicing

Fruits are manually or mechanically cored or halved after being peeled. However, to prevent enzymatic browning, peeled fruit ought to be kept immersed in either water, a 1-2% salt solution, or acid. Before canning, peaches, apricots, pears, tomatoes, etc. are peeled. However, compared to peeled fruits, fruits that have been preserved retain more nutrients.

Processing UV applications

Alternative to conventional thermal processing, ultraviolet radiation (UV) offers a lot of potential in the food processing industry. Pasteurization of juices, post-lethality treatment of meats, treatment of food-contact surfaces, and extending the shelf life of fresh vegetables are just a few of its uses. The use of UV therapy for both solid and liquid meals will be examined in this study along with published research and commercial applications. The author discusses the designs of the UV reactors that had been tried in his lab for the treatment of juice and apple cider.

The use of ultraviolet (UV) light for water treatment, air disinfection, and surface cleaning is widely known. UV light has significant promise in food production given the rising public backlash against chemicals added to meals. UV irradiation enjoys a favorable reputation among customers as a physical preservation technique. UV irradiation is safe to use, according to the US Food and Drug Administration (FDA) and US Department of Agriculture (USDA). The FDA approved the use of UV light as a pasteurization option for fresh juice products in 2000 (US FDA 2000). A 5-log10 reduction in the quantity of the particular pathogen of concern is the performance requirement established by the FDA for fruit and vegetable juice processing

UV surface treatment

In the food business, UV light is utilized to disinfect surfaces. Applications include the decontamination of conveying surfaces and packaging materials such boxes, caps, bottles, packs, tubes, films, and foils. Decontamination of equipment surfaces in bakeries, cheddar and meat facilities is another application. Although UV light is effective at disinfecting smooth surfaces, there aren't many uses for this technology in the sector of food processing. Its limited utilization may be caused by the narrow variety of commercially available solids-disinfecting equipment.

The majority of kinetic data for microbial inactivation were acquired when the bacteria were suspended in air or aqueous environments. Predicting the rate of surface disinfection using this data is not very useful. The effectiveness of UV radiation relies on the topography or surface structure because complicated interactions between microorganisms and surface substances, like shielding effects from incoming UV, may occur

Liquid foods and beverages

There is great potential for UV light to lower the levels of microbial contamination in a variety of liquid meals and beverages. Liquid foods, such as fresh juice products and drinks, transmit UV light comparatively inefficiently because they contain of colourants, organic solutes, and suspended debris. This poor transmission reduces the performance efficiency of UV pasteurisation procedures. There are significant differences in the absorbance and turbidity of clear, fresh juices versus juices containing pulp. Orange juice can have absorbances as high as 50 cm-1, but clear apple juice only has a modest absorbance of around 11 cm-1 (). Juices can range in turbidity from 1000 NTU for apple juice and other pure juices to > 4000 NTU with opaque juices like carrot, orange, and pineapple juice due to the presence of suspended materials

Reactor designs for UV treatment of juices

The inactivation efficiency can be improved by using the proper UV reactor design, which can lessen interference from some food items' high UV absorbance and viscosity. The location and duration of the microorganisms' occupancy in different areas of the irradiance source can vary greatly, and this has a considerable impact on the flow inside the UV reactor, which in turn has a significant impact on the overall UV dosage administered. For usage in pasteurizing fresh juice, many semi - continuous UV reactor concepts are currently being explored. The first design strategy reduces the route length and hence avoids issues related to poor penetration by using an incredibly thin layer UV reactor. So as to avoid issues brought by by inadequate penetration. Laminar flow and a parabolic velocity profile define thin film reactors. There are non-uniform processing conditions because the liquid's highest velocity, which is twice as rapid as its average velocity, is recorded in the middle The thin film CiderSure plant (FPE Inc., Macedon, NY) and indeed the Taylor-Coquette flow Ultraviolet reactor are the two flow designs (Forney and Pierson 2004). Low-pressure commutated lamps are installed inside a quartz sleeve that runs centrally through reactor in the Cider Sure unit.

Consumers are becoming more knowledgeable of the processes that increase the safety of food and drinks before they are delivered to grocery store aisles, whether it is greater processing or improvements to the pasteurization process. It is becoming more and more common to use ultraviolet light (UV), an electromagnetic radiation with wavelengths between 100 and 400 nanometers, to reduce or eliminate microorganisms from food and beverage items. Shorter wavelengths of this radiation, which is produced by both natural and manmade sources, endanger people more and more.

UV is divided into three groups based on wavelength. The wavelength of UV-A ranges from 320 to 400 nanometers. Sunburns are caused by this radiation, which is also frequently connected to skin cancer. UV-B has wavelengths that range from 280 to 320 nanometers, and it contributes to skin blistering and tanning. UV-B radiation is substantially less potent than UV-A. The shortest wavelength belongs to the third class, UV-C. The radiation used to cleanse wastewater, sterilise food contact surfaces, and disinfect drinking water measures within 100 and 280 nanometers. UV-C between 200 and 280 is inside the "germicidal range," according to the FDA, since it "effectively inactivates bacteria and viruses.

UV has been utilized in the food processing process. Although it is illegal to irradiate organic food, UV-C is used to process various food products, including cereals, cheese, baked goods, frozen meals, fresh vegetables and fruits liquid egg products, juices, and apple cider, among others. Due to federal rules not mandating the labelling of items treated with UV-C, supermarkets and other food sellers might not aware of this, although some states do. It has been demonstrated that UV-C can diminish or get rid of foodborne pathogens including Salmonella, Listeria, and E. coli. The amount of radiation, exposure period, and technology all affect how effective the therapy is. The technique works very quickly and efficiently on juices; it takes fewer than 30 seconds to cure 4,000 litres of juice. However, it takes more than ten years to achieve that level of effectiveness since until recently, UV technology could only be used to cure clear liquids. More thick food and drink products as well as murkier liquids may be possible to be sterilised using UV irradiation as technology advances.

Fluid mechanics

The study of fluids, whether they are moving (fluid dynamics) or at rest, is known as fluid mechanics (fluid statics). Fluids are categorized as both gases and liquids. There is a theory that can be used to solve fluid flow issues, but it should always be supported by experiment. It is a topic with excellent instrumentation that is extremely visual.

Fluid

When a material is described as fluid, it means that it has no fixed structure and is easily pliable under pressure. It could be a gas or a liquid. We refer to a fluid as having easy flow because it is more frequently used in clutches and couplings to convey power. When exposed to shear stress or an external force, a material continuously flows or deforms. One of the states of matter is a fluid, which we define as liquids, gases, or plasma. One of the scholarly descriptions of fluid is a liquid with zero yield stress, or, to put it another way, a substance that cannot withstand the application of shear stress.

Fluid Information Definition

Although we think of it as both a liquid and a gas, the word "fluid" is more closely associated with being a solid plasma. There is no shear modulus in a fluid. Let's now examine the various fluid flows:

The following forms of fluid flow exist:

a) Steady or unsteady
b) Compressible or incompressible
c) Viscous or non-viscous, and
d) Rotational or irrational.

Steady flow of fluid

If the circumstances (velocity, pressure, and cross-section) vary from to point but remain constant over time, the flow is said to be steady.

Unsteady flow of fluid

The flow is said to be unsteady if the circumstances alter over time anyone at point in the fluid.

Viscous or Non-Viscous Flow

Violent or non-viscous liquid flow is possible, Viscosity is the measure of a fluid's resistance to flow. A viscous fluid is one that presents a significant flow resistance, and its movement is described as vicious. Contrarily, a fluid with little viscosity sometimes referred to as a non-viscous fluid is said to flow comparatively readily. Its flow is also described as non-viscous. The term "viscous fluid" refers to substances that are extremely sticky, such as motor oil or shampoo.

Fluid Characteristics

The word "fluid" is used frequently and is recognised by some of its attributes. Characterstics of fluid is as follows

a) Ability to flow and quickly alter its form.
b) Constantly evolving or adaptable to changes.
c) Smooth motion, sometimes known as an effortless flow

Types of Fluids

Ideal Fluid

The fluid is referred as an ideal fluid if it is immiscible and has no friction or viscosity. There is no such thing as an ideal fluid.

Real Fluid

Real fluids are those that have viscosity. Like gasoline. Newtonian Fluid: A Newtonian fluid is one that complies with Newton's law of viscosity. For instance, glycerol-thin motor oil Non-Newtonian Fluid: A fluid is referred to as a Non-Newtonian fluid if it deviates from Newton's law of viscosity.

Newtonian fluid

A Newtonian fluid is a genuine fluid that adheres to Newton's law of viscosity. Example: Water and hydrogen

Non-Newtonian fluid:

This term refers to fluids that do not follow Newton's law of viscosity.

Ideal plastic fluid

The term "ideal plastic fluid" refers to a fluid whose shear stress is larger than the resultant and whose shear stress is exactly related to the velocity gradient.

Incompressible fluid

A fluid is said to be an incompressible fluid if its density does not change when force is applied to it. An illustration would be a fast-moving stream of water coming from the garden high pressure hose.

Compressible fluid

A fluid is referred to as compressible if its density changes as a result of the application of force. Examples include steam, gas, and vapor.

Continuum Mechanics

The mathematical explanation of deformation and associated stresses is called continuum mechanics. Materials are supposed to be homogeneous, isotropic, continuous, and free of any specific coordinate system, which is the essential premise enshrined in the name of the field. This belief is supported by Based on the intuitive belief that, despite the fact that nanoscale studies have demonstrated the discontinuous (atomic, granular, and molecular) character of matter, solid objects appear continuous at the macroscopic level, meaning that their properties appear to change gradually and without discontinuity. There are two traditional methods for expressing how fluids and material particles move. The coordinates are attached to and move through space and time with a solid point in the Lagrangian formulation .

Because they are given for a period equal 0t or are time invariant, the coordinates of the material location and the connected variables, such as temperature, do not change throughout their course. The drawback of this formulation that the points of reference shift as the fluid flows. Therefore, it is challenging to determine the fluid's state at a specific place in both space and time. In the Eulerian formulation, it is assumed that the material points move over time inside a fixed coordinate system. A partial derivative is then used to describe this change. A boat travelling through a river is a classic illustration. While the Eulerian description explains the flow as perceived from a fixed location on the river bank, the Lagrangian description represents the sequence from the viewpoint of the boat. A less idyllic comparison is to think of a flowing fluid as a race of cars, with each car representing a particle. It goes without saying that the flow of the race should be defined by the movement of each car at any given moment. The beginning point is the initial setup.

A camera is mounted on each car in the Lagrangian method to capture the race. It is true if one has to track the path taken by the automobile carrying the camera; this velocity is a function of time since the preliminary step, yet the car seems to be stationary in the camera; the car's velocity is zero, while the rest of the world is moving. The temporal and geographic continuity between the car's initial position and its place at the instant under consideration is how continuity is expressed. The Eulerian method installs cameras throughout the racetrack and keeps track of which vehicle passes each camera at what moment. While the rest of the planet is immovable, any car has speed.

The flow is defined by the total vehicle velocity at any given time. The differentiability of physical properties in space and time at any given time is how continuity is expressed. Although the Eulerian formulation is frequently seen to be more useful, both the Lagrangian and Eulerian techniques produce the same mathematical conclusion. The term "Eulerian" refers to the type of specification introduced by Swiss scientist Leonhard Euler (1707–1783) to study swift flow and the gameplay (dynamics but also kinematics) of contorting materials. It describes the flow of a fluid via volume elements at designated positions (any of the "cameras") in function of time.

Concept of continuum

A continuum is a space that can be partitioned infinitely many times without introducing new particles. It is an abstraction that allows scientists to look into how matter moves on scales bigger than for the distances between individual particles.

a) The idea of a continuum is an idealization of a continuous description of matter, in which the characteristics of the material are viewed as continuous functions of spatial variables. Despite the fact that every substance is made up of a number of molecules, the idea of a continuum assumes a continual distribution of mass inside the substance or system without no empty space, as opposed to the agglomeration of individual molecules that actually exists.
b) It is required to assume that movement variables (pressure, velocity, etc.) and fluid characteristics vary constantly from one place to another when describing a liquid motion quantitatively. This foundation has led to solid mathematical descriptions of flow, and the continuous approach of fluid medium has gained widespread acceptance. For instance, the standard definition of density at a position is
c) $$\rho = \lim_{\Delta\forall \to 0}\left(\frac{m}{\Delta\forall}\right)$$
d) Here, is the fluid element's volume and m is its mass.
e) The fluid medium's in homogeneities are a factor if is quite large. If is extremely small, which is another extreme, the total number of atoms (or compounds) could fluctuate over time due to random atomic mobility. Prior to statistical fluctuations becoming severe, the point density in the continuum model is defined at the smallest amplitude of. The symbol for this is c, which stands for continuum limit.

Conservation Of Mass (Continuity Equation)

According to this fundamental tenet, a material object's mass doesn't change throughout time. Because the examined continuous is a closed system, mass cannot be created, removed, or destroyed.This continuum object's mass is calculated by dividing its diameter by its density. For rigid-body translations or rotation, the principle of mass conservation is obvious: the item keeps its form, size, density, its volume. As a result, the object's mass does not change from its original position and orientation to its end location and orientation. The same can be easily imagined for volume-constant deformation, for instance when a cube is deformed into a parallelepiped with the same volume. Although the shape has changed, the mass, or amount of substance, has not. The fluid dynamics field frequently uses this equation. It enables the calculation of tube flow velocity. The conservation of mass states that if you know the velocity at one tube section (area), you can calculate the velocity at any other tube section. Imagine that the gate-out is half as large as the gate-in (displacement and deformation are combined). The velocity via gate-out then needs to be twice as fast as gate-in. The mass flow rate is the value of A.v ().

Conservation of energy

The total power in an isolated circuit stays constant, according to the third law of physics. Because energy is intangible, has a variety of forms, and can change forms, the concept of energy is broad and in some ways ambiguous. The conserved quantity mostly pertains to thermal energy for our purposes. Any system contains excess heat, which can be converted into or created as from kinetic and potential power generation of moving objects. These transformations or productions result in temperature fluctuations (heat gain or loss) inside the system that contains these things. Heat exchanges between system components are managed by subsequent temperature gradients.

Properties of fluids

Every fluid we work with in a lab or an industry has specific characteristics that characterize its physical behavior. These qualities are referred to as the fluids' properties. Each fluid property has unique properties that are taken into consideration while studying fluid flow issues.

Density

The mass carried by the fluid into unit volume at a particular fluid condition is referred to as density. Mass density is another name for density. Rho () is used to express it. Mathematically, it can be expressed as;

= Fluid Mass/Fluid Volume = m/V

Density is measured in Kg/m3 in the SI system and gm/cm3 in the CGS system. Mercury has a density of 13600kg/m3 at 1 atm and 25°C, while water has a density of specific gravity at 1 atm and 4.4°C. Because the variation in water's density caused by fluctuations in temperature and tension is so slight, it is typically regarded as constant for practical purposes.

Specific Volume

Specific volume is characterized as the reverse of mass density or the volume to mass ratio of a fluid. It is beneficial for compressible gaseous fluids. Its symbol is v. It can be expressed mathematically as follows: v = 1/ = V/m = Volumes of liquid of fluid

Measure of Specific volume:

- In the SI system, it uses a unit of m3/kg.

Specific weight or weight density

The ratio of a fluid's weight to volume in the gravity field is known as the fluid's specific weight. Small W is used to represent it numerically. The formula is: w = mass of dynamic of fluid or volume of fluid/volume of fluid.

$$w = \rho g$$

Because it is dependent on the acceleration caused by gravity, it could differ from one place to another.

Specific Gravity

The term "specific gravity" or "relative density" refers to the relationship between the density or "specific weight" of a fluid and the density or "specific weight" of a reference fluid. Its symbol is the letter S.

$$S = \rho f/\rho w$$

It is an indivisible amount. Air is regarded as the typical fluid for gases while water is the standard fluid for liquids. At 1 atm and 25°C, air has a density of 1.23 kg/m3. Water has a specific gravity of one (Sw). The specific gravity of common fluid is 1. A fluid will be lighter less or dense in comparison to standard fluid if it has a unit weight lower than that of standard fluid.

Viscosity

Viscosity is the ability of a liquid (liquid or gas) to resist changing its shape or allowing nearby parts to move in relation to one another. Viscosity is a sign of flow resistance. The fluidity, a metric indicating the ease of flow, is the reciprocal of viscosity. For instance, molasses is more viscous than water.

Effect of Temperature on viscosity of fluid

Because liquid molecules are tightly packed with one another, the viscosity of the liquid reduces as the degree of the liquid rises. However, as the temperature rises, this tightly packed structure fractures and the viscosity increases. Since molecular momentum transfer causes viscosity in gases, fluid viscosity in gases increases as temperature rises. Since molecular activity in gases rises as temperature rises, viscosity also rises.

Kinematic viscosity

The ratio of the fluid's dynamic viscosity to its density, or 7.25, defines the kinematic viscosity, an atmospheric variable that is affected by both air pressure and temperature. At 20 °C and sea level pressure, = 1.205 10-3 g cm3 and v = 0.15 cm2 s, respectively.

Cohesive force

A cohesive force is an antiparticle power of attraction among two molecules within the same substances. Cohesion is a feature of liquids that causes their molecules to be drawn toward one another.

Adhesive force

The force of adhesion is defined as the attraction between two or more different molecules. For example, when a glass of water is emptied, the particles remain stuck to the glass due to the molecular adhesion between the water and the glass. The ability of a fluid to cling to that other body in interaction is known as adhesion. An intermolecular force of pull between molecules of different substances is known as an adhesive force.

Surface tension

The force needed to keep a liquid's surface at a constant length, which makes it act like an elastic sheet, is known as surface tension. It takes place at the interface of two liquid surfaces or the interface of either a liquid-free surface. Surface tension forces are typically insignificant when compared to pressure and gravitational force, but they can become extremely important when there is a free surface and a narrow limit.

Hydraulic Press

A hydraulic press is a type of mechanical device that transfers energy to metals by bending and deforming them using liquid. It utilises the Pascalian principle. The equipment is mostly used to apply smaller forces higher. According to the Pascal's principle, a static fluid transmits pressure equally in every direction. The mainframe, the power system, and the hydraulic control system are the three primary components of the hydraulic press. In this, a pump that functions like a pump and generates mechanical force is used to apply pressure to a liquid.

Working of hydraulic press

Since it is simpler to regulate the thrust forces with several small rams than one huge ram, this method is used. The working load determines how many rams are needed. The ram is propelled by hydraulic fluid pressure. The high-pressure liquid is supplied by a pump and a hydraulic accumulator. Between the pump and the rams, the hydraulic accumulator functions as a connector. A hydro accumulator stores the rising liquid while the press is motionless. A pressure regulator is utilized when a task requires a powerful force.

A hydraulic press is a tool that uses a cylinder with a movable piston to provide pressure to a contained liquid, which then applies pressure to a stationary diamond or baseplate. A pump pushes the liquid into the cylinder. The hydraulic press is frequently employed in industry to mound metals and do other operations that call for a lot of force. It is produced in a wide range of shapes, sizes, and capacities, from 1 tons and under to 10,000 tones and over.

Components of Hydraulic press

Ram

The number of rams employed in a hydraulic system will vary based on the working load. To better regulate the thrust force, many tiny rams are chosen over a single bigger one. Between the rotors and the pump, there is a hydraulic accumulator that pumps fluid to the ram.

Accumulator

Hydraulic pressure is kept in the accumulator as a fluid and discharged as needed. A hydraulic accumulator is designed as a cylinder with a spring-loaded or pneumatically pressured piston. To maintain a consistent pressure in the accumulator, the pump continually pushes hydraulic fluid into it. The pump serves as the accumulator's inlet, while the machine serves as its output. The pump would have to operate continuously without the accumulator. By acting as a reservoir for the energy required to run the machine, the accumulator helps to prevent this.

Pump

Vane, gear, and piston pumps are the three different types of hydraulic pumps; piston pumps are the most often utilized. Positive displacement pumps, which provide a fixed volume of fluid among each pumping cycle, are used in hydraulic presses. A variable area pump can really be fixed or variable, with the former operating at a set speed and the latter capable of reversing. Because of its effectiveness in high pressurhigh-pressuree hydraulic systems, piston pumps are ideally suited for hydraulic presses. The pump's minimal fluid loss allows it to function at high volumetric levels. Axial, bent-axis, and radial piston pumps are the different varieties.

Cylinders

A hydraulic press's design affects how many cylinders it has. The cylinders' job is to produce the compressive force needed to move the anvil and die. In a two-cylinder design, the ram-carrying cylinder has a larger diameter than the plunger-carrying cylinder, which has a smaller diameter. With two ports for hydraulic fluid input and outflow, cylinders are metal pipes. A hydraulic fluid-filled conduit connects the cylinders. The hydraulic fluid is put under pressure when the lever in the tiny cylinder pushes downward, applying the produced pressure to the ram.

Hydraulic Press Process

A plane slug is placed beneath the anvil, and pressure from the cylinders powers a ram that pushes the anvil down into in the slug and presses it into the die, showing the mechanical effects of the pressure exerted in the hydraulic system.

Types of Hydraulic Presses

The fabrication, assembling, and manufacture of parts for industrial and commercial items as well as mechanical components heavily rely on hydraulic presses. The frame and metals utilized in their construction, as well as other elements, are what differentiate the various types of hydraulic presses. The capacity of hydraulic presses to apply significant compressive stress to billets in order to flat, shape, bend, stamp, etc bend these billets into patterns and other forms accounts for their widespread usage in manufacturing. With the use of range of dies, the hydraulic press method may be modified to meet a variety of industrial needs.

H Frame Hydraulic Press

A hydraulic press with an H frame (two columns) has a "H"-shaped frame, press chamber, pump, and bolster. H frame presses are employed in a variety of settings, such as production assembly lines, maintenance facilities, and repair facilities. For low volume applications, they have a hand pump available, or air and electricity pumps where dependable operation is needed. The size of the cylinder in an H frame determines how much force is available.

C Frame Hydraulic Press

Hydraulic presses with a single column (or "C frame") feature a body frame shaped like the character "C" with the single arm arrangement. They are exceptionally fast, stiff, function well as guides, and have great accuracy. They demand less floor area and are perfect for small companies.

Pascal's law

A pressure drop inside one area of a fluid at rest in such a closed container is transferred without loss to all areas of the fluid as well as the container walls, according to Pascal's principle, sometimes known as Pascal's law. The French physicist Blaise Pascal initially stated the principle. The force multiplied by the surface area which it acts produces pressure. Pascal's principle states that a pressure rise on one piston in a hydraulic circuit causes an equivalent pressure on this other piston there in system. Even though the pressure on the second piston is equivalent to that on the first piston, the force acting on it is 10 times more if its area is 10 times greater than the first piston's.

The hydraulic press, which is based on Pascal's concept and is employed in systems like hydraulic brakes, is a good example of this effect. Pascal also observed that the force at a fluid's resting point is the same across all directions; hence, the pressure would remain the same on all planes travelling through a given place. Pascal's law or the Pascal's principle are other names for this truth.

Absolute Pressure

Absolute pressure is defined as any pressure that is found to be greater than zero. It is determined by using a barometer and is determined by adding the atmospheric pressure to the measurement of pressure. the atmospheric pressure in patm.

Absolute vs gauge pressure measurement

It is pretty simple to understand how the two measurements differ: with a gauge pressure calculation, the deviation from the present ambient pressure is always measured. However, this pressure varies according to the climate and altitude above sea level. A measurement of absolute pressure computes the deviation from the ideal or perfect vacuum. The two measurements may typically be distinguished by doing the following: determining the gauge pressure is typically the measuring task. This explains why this kind of sensor is the most prevalent. However, the following additional mistakes must be anticipated if a pressure transducer sensor is utilised in a situation where the actual measurement task is to record the absolute pressure:

+/- 30 mbar due to geographical changes and weather variations of up to 200 mbar (e.g. from sea level to 2,000 m)

Manometer

Manometers are devices that measure the pressure at a specific place in a liquid by balancing the fluid column with the same or another fluid column. They are categorized as:

1. Simple Manometers
2. Differential Manometers.

Simple Manometers

A basic manometer is a glass tube with one end attached to the location of the measurement of pressure with the other end left exposed to the atmosphere. Simple manometers of the following popular types:

a) Piezo meter
b) U-tube manometer,
c) 3. Manometer with a single column.

Piezo meter

It is the most basic type of manometer used to gauge pressure. This manometer has an open end that is exposed to the atmosphere and one end that is linked to the location where pressure will be monitored. The Piezometer's rising liquid level indicates pressure head at point A.

U- Tube Manometer

It sealed glass bent into a u shape, with one end linked to the measurement site and the other end left open to the ambient. Usually, the tube is filled with mercury or another liquid whose unit weight is higher than the stream whose pressure is being measured.

Single Column Manometer

A single column manometer is a refined version of a U-tube manometer in which one of the limbs (let's say the left leg) of the manometer is linked to a reservoir with a huge cross sectional area (approximately 100 times) is compared to the area of the tube. The change in the fluid in the reservoirs will be extremely minor and may be disregarded due to the vast cross-sectional area of the reservoir, hence the pressure is determined by the height of liquid in the other limb. The opposite limb might be horizontal or angled.

Differential Manometers

Differential manometers are now the tools used to gauge the pressure differential between two places in the same pipe or between two pipes. A hefty liquid-filled U-tube with its two ends linked to the places whose pressure difference is to be measured makes up a differential manometer. Differential manometers are instruments for determining the difference in pressure within a pipe or between two pipes. A heavy liquid-filled U-tube with two linked ends that are attached to the sites where the pressure difference has to be measured makes up a differential manometer.

Hot break and cold break

Proteins and polyphenols in Hot Break coagulate as during wort boil, ultimately forming large enough flocs (chunks) to separate from solution and fall to the kettle's bottom. The hot break often happens 5 to 30 minutes after a strong boil has started. In brewing, a cold pause is beneficial. It lessens the effects of chill haze and gives you a much clearer brew as a result. The proteins in the wort are what create cold break. Cold break will occur at 140°F IF the wort is rapidly cooled.

Fruit Powder

Dried fruit that has been finely powdered is known as fruit powder. Fruit powder may be used to flavor almost anything instead of artificial flavoring. However, sweets, where the balance of moisture is crucial, are where fruit powder really shines.

a) Fruit powder made from mango
b) Powder made from pomegranate fruit
c) Powder made from papaya fruit

Mango Fruit Powder

Unripe, tart mangos are cut into slices and sun-dried before being processed into mango powder. Mangoes are a native of Southwest Asia and are also referred to it as amchur or anchor powder. The majority of people are aware of the exquisite sweetness of mango. The contrary is true; this powder is quite sour and unpleasant.

Although mango powders is not technically a "spice," it can be employed in the same manner as tamarind, lemon, or lime juice is used to enhance sourness. The fact that this powder is utilized in vegetarian foods, curries, chutneys, pastries, soups, and marinades makes it most closely connected with Northern Indian cuisine.

Pomegranate Fruit Powder

The pomegranate fruit is berry-like in shape and has a leathery skin (husk or peel) that protects many seeds and juicy arils. Pomegranate seed oil (PSO), which accounts for 65% to 80% of oil from pomegranate seeds, has an outstanding conjugated polyunsaturated acidic taste pumices acid (trienoic acid).

Papaya Fruit Powder

Papayas contain the digestive enzyme papain, which may also be used to tenderise meat. Additionally, papaya has a lot of water and fiber, both of which aid to maintain regularity and just a healthy digestive system.

Vegetable Powders

To provide a potent combination of nutritional advantages, including fibre, vitamins, and phytonutrients within nutraceuticals supplements, vegetable granules can be used alone or coupled with fruit powders. In order to assist prevent cell damage, vegetable powders also include carotenoids, which can counteract free radicals.

a) The tomato
b) Onion

Tomato Powder

To add that familiar tomato taste to any recipe, tomato flour is the ideal addition. It tastes great in smoothies, with soups or sauces, and with eggs. Lycopene, b Vitamins, and many other beneficial elements are abundant in tomato powder, which is produced from dried tomatoes.

Onion Powder

Dehydrated, crushed onion is what is known as onion powder and is frequently used as a flavouring. It frequently appears in salted salt and spice blends like beau monde seasoning. Some variants call for toasting the onion.

May use white, yellow, and red onions. An industrially produced food item called onion powder has a variety of culinary applications. One can even make their own onion powder.

Fruits and Vegetable Powder Market

Manufacturers in the grocery business are concentrating on adopting health-beneficial food items as a result of the movement in consumer preferences toward healthy products. Food producers are powderizing raw fruits and veggies in order to give healthful food items. Fruit and vegetable powder is used as a key component in the creation of flavorful, creative food items by the food industry and food retail establishments. Fruit and vegetable powders is said to be a great method to add the flavour of out-of-season fruits and vegetables to culinary products. The need for fruits and vegetable powdered will mostly come from North America and the Asia Pacific region in the worldwide market for fruits and vegetables. The majority of the world's fruits and vegetable powders is produced in Asia Pacific.

The growing number of vegans throughout the world is driving up demand with fruits and vegetable powder on the global market. Fruit and vegetable powdered is simple to store and extends product shelf life. Aside from that, this powder may be consumed all year round. Fruit and vegetable flour is used in the foodservice industry to flavour and enhance foods and beverages. Additionally, the usage of this powder aids in regulating the cost of fresh produce at the beginning of the season. Leading businesses are focusing on developing cutting-edge, application-specific goods to maintain their market leadership.

A bright outlook for the nutraceuticals sector is predicted to cause the global market for fruit powder to grow to USD 23.96 billion by 2025. Through functional foods and beverages, consumers constantly strive to meet their nutritional needs. The demand for products has expanded as a result of growing understanding of the significance of micronutrients such vitamins, enzymes, and amino acids. Customers are more likely to choose convenience foods that suit specific nutritional needs as lifestyles change. The market for fruit powder will be fueled by the aforementioned developments since they have increased demand for nutraceuticals.

Heat Transfer

Any substance with atoms and molecules in it has the capacity to transport heat. At any one time, the atoms are moving in a variety of ways. Every substance possesses this thermal energy, which is produced by the motion of atoms and molecules. The amount of heat energy increases with the amount of molecular mobility. But when it comes to heat transfer, all that is meant is the action of moving heat from a body that is hot to one that is cold.

Heat Transfer Definition

The transfer of heat over a system's boundary as a result of a temperature differential between the and its surroundings. Heat transfer is any or all of a number of events that are thought to function as mechanisms to move energy or entropy from one place to another.

There are several methods for heat to go from one area to another. The many heat transmission mechanisms consist of:

a) Conduction
b) Convection

c) Radiation

Heat will still find a way to go from the upper to the system if the two systems have a temperature differential.

Conduction

Thermal energy is transferred from a region with higher kinetic energy to an area with lower kinetic energy. Slow-moving particles gain kinetic energy as a result of collisions between high-speed and slow-moving particles. This common type of heat transmission occurs when two objects physically touch. Thermal conduction and heat conduction are other names for conduction. Heat energy is transferred through the mechanism of conduction when nearby atoms or molecules collide. In solids and liquids, where particles are more closely spaced, conduction happens more easily than in air, where particles are more widely spaced.

Temperature gradient, material cross-section, length of migration route, and physical qualities of the material are all elements that affect the mechanism of heat conduction. The physical parameter that describes the route and rate of heat conduction is the temperature gradient. The movement of temperature will always be from warmest to coldest hence, as previously said, from greater to lesser kinetic energy. The thermal transmission ceases when the two temperature disparities reachthermal equilibrium.

Convection

The thermal energy is transferred when a fluid, such air or a water, is heated and subsequently moves away from the source. Convection is the name for this form of heat transmission. A heated surface causes the fluid above it to expand, lose density, and rise. When heat energy is introduced, molecules there at molecular level expand. The volume of the water must grow by the same factor as the temperature of the specified fluid mass. The fluid is displaced as a result of this process.

Examples of convection

- When water boils, the molecules move in a circular motion because the less dense ones migrate higher while the denser ones move toward the bottom, causing the water to get heated.
- Cooler water just at poles goes towards the equator whereas warm water near the equator does the opposite.
- Warm-blooded animals' bodies use convection to facilitate blood circulation, which controls body temperature.

Radiation

Our daily lives include radiant heat in one way or another. Radiant heat is the name for thermal radiations. Emission of electromagnetic fields results in the production of thermal radiation. The power from the producing body is removed by these waves. A vacuum, transparent media, which can be made of solid or liquid, is used for radiation transmission. The random mobility of matter molecules produces thermal radiation. Emission of electromagnetic energy is caused by the motion of charged protons and electrons. Electromagnetic waves emit and produce thermal radiation. The energy is carried away from the generating item by these waves.

Radiation may pass through any transparent material, including a vacuum (either solid or fluid). Thermal radiation is a direct effect of the unpredictably moving atoms and molecules that make up matter. Thermocouples are instruments used to quantify heat transfer by radiation. The temperature is measured using a thermocouple. When this gadget measures temperature by radiation heat transfer, errors can occur. Depending on their temperature, every material emits thermal energy. An item will emit more the hotter it is. A prime example of thermal radiation that moves heat from across solar system is the sun. Infrared radiation are emitted by items at standard room temperatures. The wavelength or frequency of the emitted waves are influenced by the object's temperature. A solar cell, also known as a photovoltaic cell, uses the photovoltaic effect to convert light energy into electrical energy. A higher energy state of the electrcon is excited by light absorption, and the separation between charges creates the electric potential. In recent years, solar panels' efficiency has increased.

Emissivity

The ratio of energy emitted from a surface (e.g. to the energy emitted from a blackbody, a perfect emitter with the same temperature, wavelength, and viewing circumstances, is known as emissivity. It is an arbitrary number without dimensions between 0 (for an ideal reflector) and 1.

Forced convection

In order to improve the heat transfer, fluids are pushed to circulate during a unique form of heat transfer called forced convection. An air - conditioning, a pump, a suction tool, or another tool can be used to force anything. The phrase "heat rises" is well known to many people. The concept that heated fluids are often less dense than a similar fluid when cold is simplified in this fashion, but there are certain anomalies Due to the increased float of the hotter material and the difference in density, the hotter material will inevitably end up on top of the cooler substance.

Natural convection

Natural processes, such as buoyancy, are used to move the fluid in natural convection. Natural convection experiences a low heat transfer coefficient since the velocity of the water associated with it is likewise relatively low. Natural convection, often referred to as free convection, is a process, or form of mass and heat transfer, in which fluid motion is produced only by density variations within the fluid that arise as a result of temperature gradients, rather than by any external device (like a pump, fan, suction device, etc.). Natural convection occurs when fluid near a heat source absorbs heat, loses density, and rises as a result of thermal expansion. The fluid's thermal expansion is of utmost importance. In other words, there will be a movement of the bulk fluid as heavier (more dense) particles sink and lighter (less dense) elements rise.

Blackbody Radiation

Natural convection, often referred to as free convection, is a process or style of mass and heat transfer in which fluid motion is produced only by density differences in the fluid that arise as a result of thermal conduction, not through any independent factor (like a pump, fan, suction device, etc.). When a heat source is nearby, a fluid acquires heat, loses density, and rises as a result of thermal expansion. The fluid's thermal expansion plays a key part. In other words, there will be bulk fluid movement because heavier (more dense) elements will sink and lighter (less dense) parts will rise. A body is considered a black body if it completely collects all radiation that strikes it. Although a hole in a large box with extremely absorbent material can approach the features of a black body, true black bodies do not exist in nature. Max Planck was the one who first thoroughly defined the emission spectra of this type of black body.

A hypothetical entity known as a "black body" totally absorbs all thermal radiation wavelengths that are incident onto it. When such bodies' temperatures are cold enough to prevent them from becoming self-luminous, they don't really reflect light and look black as a result. Thermal radiation is produced when a dark body is heated to a certain temperature.

Specular and Diffuse Reflection

The degree of smooth reflected or texture of a surface has a significant impact on the amount of sunlight reflecting by an item and on how it is reflected. Nearly all of the light is evenly reflected when surface flaws are shorter than the visible wavelength (as in the situation of a mirror). In contrast, the majority of things in the actual world have wavy surfaces that reflect light in all directions and produce a diffuse reflection. This interactive course investigates the reflection of light waves by both smooth and uneven surfaces.

Radiative heat transfer

Thermal electromagnetic radiation, which develops as a result of a body's temperature, mediates radiation heat transfer. Any substance that has a temperature higher than absolute zero emits some radiant radiation. Heat is the energy that spontaneously transfers from one substance to the due to a change in temperature. Although it is an energy form, heat is energy in motion. Typically, many processes are used to classify heat transmission, including:

Conduction of heat

Diffusion, another name for heat conduction, happens within between or two interacting bodies. It is the light microscopy transfer of particle kinetic energy across the border of two systems

Convection of heat.

The transfer of mass from one space region to another is necessary for heat convection. When heat is carried in the bulk flow of a fluid (gas or liquid), this is known as heat convection.

Thermal Radiation

Radiation is the process of transferring heat by electromagnetic energy, such as sunlight, without the requirement for an air gap between the substances. Thermal electromagnetic radiation, which develops as a result of a body's temperature, mediates radiation heat transfer. Any substance that has a temperature higher than absolute zero emits some radiant radiation. Although some of this sort of energy is located in the visible spectrum, the majority of it is in the infrared area. The Earth's reception of solar radiation and subsequent emission of thermal radiation are two of the most significant instances of radiation heat transfer. The Earth's climate and temperature are determined by these processes.

Thermal Radiation

Electromagnetic radiation, sometimes referred to as thermal radiation, which results from a body's temperature, mediates the transport of radiation heat. Radiant energy is released by any substance having a temperature higher than absolute zero. The electromagnetic spectrum's infrared area contains the majority of this form of energy, however some of it also exists in the visible range. The Earth's solar radiation absorption and subsequent thermal radiation emission are two of the most significant instances of radiation heat transfer. These mechanisms control the Earth's climate and temperature. There is no medium needed for the energy transmission in thermal radiation. The quickest way to transport energy is by radiation, which travels at the light speed of light and experiences no retardation in a vacuum.

Electrical Machines

Generator

A generator is a device that converts electrical energy from mechanical energy through the use of magnetic induction. This is feasible because of the rotation of coils in a magnetic field, or because of the rotation of two magnets around a stationary coil, or because of a generator that consists of internal fields.

An Electric Generator: Working Principle

The generator is composed of a coil with many copper wires wound around an iron core that is rectangular in shape. The armature is the term for this coil. This armature's purpose is to boost the magnetic flux. The armature revolves between two powerful permanent magnets that have been set. Here, the magnetic lines that are created are orthogonal to the axis of the armature. Two slip rings are further attached to the armature's arms.

Two metallic brushes are also linked to the slip rings, which aid in moving current first from armature to the slip rings. These rings are employed for providing movable contact. Last but not least, the current flows through a load that is wired in parallel with and across the three slip rings. At various time intervals, the armature's location is continuously changing. The coil is spun in the magnetic field at the point where the magnetic lines are horizontal to the coil in order to increase the produced induced e.m.f. This is where it happens since there are the most intercepting magnetic field lines.

Types of Generators

AC Generators

A device that transforms mechanical energy into electricity is an AC generator. Mechanical energy is provided by power plants, gas turbines, and combustion engines as the AC battery's input source. Pulsed electromagnetic electricity in the form of current and voltage is the output.

Induction Generator

An induction generator, also known as an asynchronous generator, is an a kind of pulsating dc (AC) electrical generator that generates power using the fundamentals of induction motors. Induction generators work by turning their rotors mechanically faster than fixed speed. A standard alternating current induction motor can usually be used as a power source without any intrinsic modifications. Electromagnets are useful for uses such as mini hydroelectric plants, wind turbines, and reducing higher oxygen streams to reduced density because they can fully heal energy of relatively simple controls.

Synchronous Generators

These are large generators that are commonly found in power plants. These are the rotating spectrum or armature types. The armature is at the rotor end of a rotating armature, and the field is located at stator end. Cleaners and slip rings conduct current through the rotor armature. These turbines are used in applications with low power requirements. However, because of its high power production capability and lack of the need for slip rings and brushes, the rotating field category of alternate or is broadly used.

Two-phase or Three Phase-Generators

The two-phase generator produces two voltages, each of which is deemed a single-phase voltage. However, the created voltages are not completely dependent on one another. The three-phase dc generator has three single-phase windings spaced apart so that the voltage formed in any one phases displaces the power supply generated in the other two. These generators are utilized in a variety of applications such as naval, oil and natural gas removal, wind power plants, and mining machinery, among others.

Application Advantages of AC Generator

These Generators were also generally repairs because they do not require brushes.

a) These generators are smaller in size than DC generators.
b) Losses are lower than in DC machines.
c) Ac power breakers are much smaller than DC breakers.

DC Generators

The direct current generator converts mechanical power into direct-current electricity. It is commonly found in off-grid applications. Without the need for novel equipment, these generators provide continuous electricity supply directly into electrical energy storage machines and Washington power grids. The working principle of the DC generator is also based on Faraday's law of electromagnetic induction. An electromagnetic force was indeed induced in the conductor when it is placed in a varying field. The severity of this induced emf can be calculated using the emf - formula for DC generators. Circulation of induced current occurs within its closed circuit.

Transformer

The voltage is converted as greater or lesser voltages by the device. When electrical power is produced during the transfer, different voltage levels are used. A transformer is typically composed of two coils, primary/field and secondary/inductance, which are kept apart so that no electrical contact occurs between them. When we allow current to flow through primary coil, a magnetic field is generated that changes. However, the frequency remains constant. It produces an alternating voltage across the secondary coil while at the same time. During a closed electrical circuit, an alternating current flows through a secondary coil. They are exactly proportional, meaning that the voltage differences between the primary and second coils will also increase with the difference in the amount of windings between those coils.
