MANAGEMENT OF AGRICULTURAL LAND: CLIMATIC AND WATER ASPECTS

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Contents

Summary

This chapter deals with the management of agricultural land, in particular with respect to climatic and water aspects. Climate affects crop production directly through temperature and rainfall, and additionally through air humidity and radiation. Rainfall and moisture have also an indirect effect on field operations. Adverse climatic hazards, like extreme temperatures, can be overcome by adapting the crop calendar (annual crops) or through some sophisticated techniques (perennial crops).

Agricultural production and activities have a problem when either too much or too little water is available in the root zone. A shortage of water can be compensated by irrigation. There are three major irrigation systems, involving pressurized water distribution (sprinkler, drip or trickle irrigation), surface irrigation and gravity flow (basin and furrow irrigation), and controlled drainage flow or subsurface irrigation. Excess water has to be drained off, either by surface drains (or open ditches) or by subsurface mole or pipe drains. Tillage operations are affected by the moisture status of the root zone.

The theoretical considerations discussed in the first part of the chapter are illustrated with a case study of an irrigation project in the Senegal River basin.

1. Introduction

Agricultural land is by definition land that is, or can be used for agriculture and crop farming. Agriculture focuses mainly on the cultivation of soils for annual or perennial crop production, vegetables and fruits. It involves the preparation and proper care of the soil, sowing and planting, seed and crop variety selection, protection against pests and diseases, and harvesting. In a broader sense, agriculture includes also gardening or horticulture, and the raising of livestock. Agricultural land management involves all these aspects and is therefore multifaceted.

Land has properties - good or bad, temporary or permanent - that make it suitable or unsuitable for agriculture. Some of these properties can be corrected or adjusted, others do not. Clearly, agricultural land management has to focus (1) on the conservation of those land properties that contribute positively to production and soil health (by maintaining them in an optimal state and by avoiding their degradation), and (2) on the reclamation of those properties that hamper optimal production. Land management in general, and agricultural land management in particular, is therefore primarily determined by (a) a combination of technical criteria, (b) farmer’s know-how to deal with natural resources and constraints, and (c) economic considerations of profitability.

2. Types of Agricultural Land Management

Agricultural land management deals with the production of annual or perennial crops, fruits and tree crops, and grassland. All of these have their own requirements in terms of climatic growth conditions, root development, water and nutrient uptake, photosynthetic activity and biomass production and, additionally, field preparation and harvesting conditions. Moreover, as land use has to be operated in a spirit of sustainability and conservation of the natural environment, all management operations have to be achieved in view of a proper care and maintenance of soil health. Hence, five major types of agricultural land management can be differentiated:

- management aspects related to climatic conditions or constraints;
- management activities related to crop moisture supply;
- management activities related to fertilization and nutrient supply;
- management activities related to workability, field preparation and harvesting; and
- management aspects related to soil care and sustainability.

In this chapter the main focus will be on the agricultural land management of climatic and water aspects, with some additional considerations to soil workability and land preparation. The other issues will be discussed in a companion chapter dealing with chemical and fertility aspects of agricultural land management (see: *Management of Agricultural Land: Chemical and Fertility Aspects*).

3. Agricultural Land Management related to Climatic Hazards

Climate affects crop production primarily through temperature and rainfall, and additionally through air humidity and wind. Rainfall and moisture influence also indirectly agricultural field operations. Optimizing climatic growth and production conditions involves that the positive climatic conditions are exploited to a maximum while the adverse effects of the harmful factors are reduced or waved away.

3.1. Managing Temperature Constraints

The importance of temperature as a growth factor depends on the type and sensitivity of the crop. Some crops like rubber or cocoa need high energy inputs and suffer already when minimum temperatures drop below 15° C. Others, e.g. most vegetables, grow best in cooler climates. A third group, like maize, has developed a great adaptability and can now be cultivated over a wide range of world climates.

Managing temperature hazards can be achieved in two ways: for annual crops the growth calendar can be adapted in order to avoid adverse seasonal conditions; for perennial crops this is more difficult and, unless sophisticated methods are used, the areal extension of the crop will be restrained by the occurrence of the most critical climatic parameter.

3.1.1. Average Temperature

Though average temperatures have little meaning for crop growth *in se,* mean monthly temperature determines the distribution of crops in the world or, for a given crop, defines the high-productive from the less suitable production areas. Oil palm, coffee or cocoa are typical crops of the humid tropics which require high temperatures (and rainfall). Therefore, they cannot be grown successfully outside the inter-tropical belt. Even in areas where average day temperature is 22-25° C, but night temperatures drop below 16-18° C oil palm suffers from diseases and lower production. The successful cultivation of maize and other grain crops is mainly determined by the length of the growing period (Fig. 1).

A similar situation occurs for coconut palm which requires high average temperatures (above 22° C) but does not support daily variations of more than 5° C; for this reason coconuts are only encountered in tropical lowlands, in particular along coastlines. Under these conditions large-scale plantation agriculture for this type of crops is restricted to the suitable climates, and the most adequate management policy is to limit their extension to those areas.

3.1.2. Low Temperature

Low temperatures are critical for many crops, and quite a number of higher plants go into a dormancy period when air temperatures drop below 5° C. The critical temperature below which the crop is damaged depends on the growth stage, degree of cold hardening and even mineral nutrition. Ice formation in the intercellular spaces is generally lethal to plant tissues, and is the normal cause of frost damage in plants. Some plants have nevertheless the ability to move into a super cool stage, and this phenomenon explains why some crops, like banana for instance, can support light frosts up to -3° C without major production loss.

Annual crops can relatively easily overcome low temperatures over a short period in the year. Rice production in the Senegal River floodplain for example suffers from the low night temperatures in December-February and requires therefore that the crop calendar is adapted (see Section 5: Case study).

A similar situation occurs in tropical highlands (as for instance in Rwanda) where in valleys above 1500 m altitude the night temperatures in May-June drop as low as 5-7° C. Under those conditions the rice panicles are incompletely filled, and harvests are substantially lower. By adapting the crop calendar rice production is nevertheless very successful in these regions, whereby yields up to 2.5-3 tons/ha can be obtained under farmers' conditions.

Some crops on the other hand need explicitly low temperatures to stimulate growth. This is the case for winter wheat which requires a cool vernalization period to stimulate germination and early vegetative development. It explains also why wheat cannot be grown in the tropics unless in high-altitude or desert areas with cool nights.

The problem is more difficult for perennials, though even then an adapted management can technically overcome short-term low temperatures. Because of the extra costs involved these techniques are only implemented for high-value crops.

Moreover, protection against frost (or otherwise low temperatures) is normally only profitable when frost in the growing season is not frequent, as is the case for example, of winter frosts in Mediterranean climates or spring and autumn frosts in more temperate regions. In some vineyards in Germany, Luxemburg, and the Vosges and Savoie regions in France light frost damage in spring is overcome by installing a temporary sprinkler irrigation system, or a smoke curtain in the fields. Likewise ground sprinkling is employed in deciduous fruit and nut orchards in northern California.

3.1.3. High Temperature

Excessive maximum temperatures are rarely reported in crop production. Often, these are associated with other factors such as radiation and crop-evaporative demands. Maize, some types of beans and tomatoes are typical examples of crops that are sensitive to temperatures above 35° C; sorghum on the other hand is well adapted to those conditions and stands temperatures above 40° C without apparent harm. The problem of maize is that it suffers from excessive evapo-transpiration, while in the case of tomatoes the flowers are dropped and fruits malformed. The sensitivity of beans is, nevertheless, only limited to a specific period in the growth cycle. The most direct management solution in these cases is either to adapt the crop calendar (annual crops), to introduce a cover crop which creates more shadow and a cooler microclimate, or to change to alternative and better adapted crops.

3.2. Managing Rainfall Constraints

Rainfall is, together with temperature, the major climatic component in crop production, and the primary source for plant moisture supply. Problems related to an inadequate rainfall refer either to a shortage or to an excess of rain. Rainfall characteristics in combination with temperature criteria determine the distribution of the major crops over the world (Fig. 1).

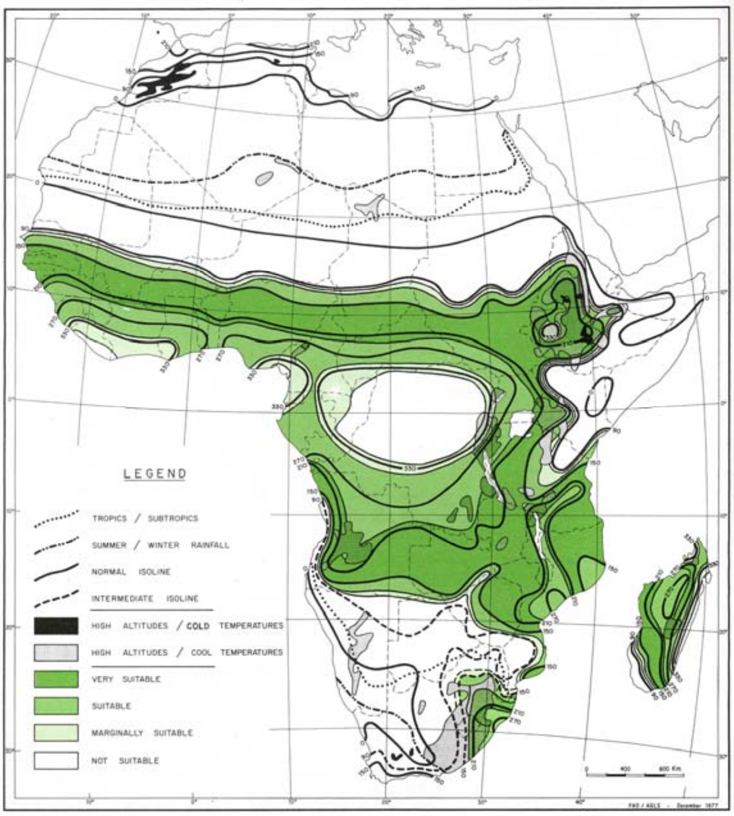

Figure 1: Aerial extension of major production zones for maize in Africa south of the Sahara (FAO, 1978)

The rainfall regime in terms of precipitation amount and distribution over the year affects in the first place the length of the growing period - that is the period in the year that crop growth is not hampered by moisture (and temperature) limitations - and, in this respect, it has a direct impact on the nature of the crops grown and on the quantity and quality of the yield. This growing period can directly be derived from a water balance model involving rainfall (moisture input), crop-evaporative demands (moisture output) and soil water holding capacity (water storage) as described in more detail in *The FAO Guidelines for Land Evaluation.*

The nature of the growing period indicates to what degree rainfall is satisfactory for physiological plant growth. Three situations can hereby be differentiated:

- rainfall amount and distribution are equal or overpass the time of the growing period: the crop can satisfactorily be cultivated;
- rainfall amount and distribution are smaller than the time needed for normal plant growth : either an additional irrigation is required to extend the growth cycle, or crop yields are lower, or the crop can no more be satisfactorily grown and has to be replaced by a crop with less exacting water requirements;
- rainfall distribution is irregular, showing intermediate dry spells: different management options remain open depending on: the length of the dry spells, the importance of the water deficit, and the nature of water source available.

Though in general it is the overall moisture supply that governs crop development, many crops are particularly sensitive during some critical periods in their growth cycle. Table 1 shows that flowering and, to a lesser extent heading, is often the most sensitive period.

Crop	**Most critical periods for water deficit**
Barley	Shooting and earing
Cabbage	Head formation
Cauliflower/ Broccoli	All stages (curd production)
Cotton	Flowering and boll development
Maize (corn)	Flowering and early grain formation
Oats	Heading and flowering
Onions	Flowering (seed production)
Peanuts	Flowering and seed development
Peas	Flowering and pod filling
Potato	Tuber initiation through maturity
Rice	Heading and flowering
Rye	Flowering and early grain formation
Sorghum	Booting (end of shooting stage prior to emerge of head) and heading
Soybeans/Other beans	Flowering and pod set
Sunflower	Heading and grain filling
Wheat	Shooting and earing

Table 1: Critical growth periods for water deficits in selected crops
(from Salter and Goode, 1967, in: T.A. Howell, 1990)

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Biographical Sketch

Willy Verheye is an Emeritus Research Director at the National Science Foundation, Flanders, and a former Professor in the Geography Department, University of Ghent, Belgium. He holds an MSc. in Physical Geography (1961), a PhD. in soil science (1970) and a Post-Doctoral Degree in soil science and land use planning (1980).

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