SECTION 2

The Choice of First-Order Impact Models for Semi-Arid Regions

Timothy Carter and Nicolaas Konijn

2.1. Introduction

The variability of rainfall in space and time is such that, even in climates that are classified as humid, crop yield losses due to limited water availability can occur. In these circumstances the effect of a dry spell can often be minimized through the use of supplemental irrigation. However, in semi-arid regions not only is rainfall limited, but supplementary water resources are often absent, too, and irrigation of agricultural crops is possible only in restricted areas. Thus, agricultural production in these areas is based mainly on rainfed agriculture.

A rainfed production environment is very sensitive to relatively small variations in the climate. It requires from the farmer the capacity for rapid adjustment and adaptation to prevailing conditions. For example, the carrying capacity of the land for livestock may fluctuate markedly from year to year, and grasslands that are suitable for livestock one year may deteriorate quickly under adverse conditions the next. Difficulties associated with overgrazing, including the possibility of irreversible changes in the production environment through soil erosion, are an ever-present danger unless checked at an early stage. Attempts to model agricultural production in semi-arid regions therefore require an understanding of the production environment, the range of plant and animal responses and the tools available to the farmer to reduce the negative effects of water stress on crop and livestock productivity.

In this section, we provide a general introduction to the types of models that have been used in this volume for estimating the first-order effects of climatic variations on agricultural production in the semi-arid case study regions. We begin by describing some characteristics of agricultural production in semi-arid areas, including the physical constraints on agriculture, types of crop, cultivation practices, livestock production and other limiting factors. We next

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examine some methods of estimating the effects of climatic variations on agricultural production. The development, testing and use of agroclimatic models in climate impact assessment are discussed in depth in the companion volume (Carter *et al.*, 1988). Here we concentrate on aspects of particular importance for applications in semi-arid regions and consider, in addition to agroclimatic models, the use of livestock models and agroclimatic zonation schemes. These are illustrated with examples from the regional case studies and summarized in a model checklist.

2.2. Climatic Variations and Agricultural Production in Semi-Arid Regions

2.2.1. Characteristics of the physical production environment

Before characterizing particular features of semi-arid regions, it is useful to identify the geographical location and extent of these areas. We have adopted a climate-based classification of dry regions both to identify the distribution of semi-arid zones and to illustrate, in the most general terms, the average global moisture regime. Other possible classification criteria are discussed in Part I, Section 3. Subsequently, we have related these climatic zones to characteristic soil types.

Average moisture regime

Figure 2.1 shows the extent of dry regions based on the Thornthwaite (1948) moisture index and refined by grouping areas with a similar seasonal distribution of precipitation and similar temperatures for the coldest and warmest months (after Meigs, 1953). Three degrees of aridity are delimited: extremely arid, arid and semi-arid. The correspondence of these zones with the case study regions investigated in this volume can also be noted.

One of the characteristic features of semi-arid regions not illustrated in *Figure 2.1* is the high interannual variability both of the total and the distribution of precipitation. This, of course, has a critical bearing on year-to-year agricultural productivity, and forms a central theme of this section. A global-scale map of precipitation variability is presented in Section 3 (*Figure 3.8*).

Dominant soils

It is natural to expect the large-scale climatic zones (such as those depicted in *Figure 2.1*) to be mirrored closely by the spatial distribution of major soil classes. *Figure 2.2* provides a global picture of the distribution of soils over the three dry climatic zones identified above. It is based on the US Comprehensive Soil Classification System – 7th Approximation (Soil Survey Staff, 1960; 1976). Only the soils at the highest level of taxonomy (broadest category) are presented. This is a morphometric system where soils are classified in accordance with their