SECTION 2

Effects of Monsoon Variability on Agriculture

2.1. The Setting

In the tropics the most important climatic element for agriculture is rainfall. The dependence of Indian agriculture on monsoon rainfall is well known (Swaminathan, 1983); in fact, the Indian economy has been described as a gamble on the monsoon rains. We thus expect any climatic change involving a large-scale change in rainfall to have a significant impact on agricultural productivity. However, as pointed out in Section 1, there is no evidence for long-term increasing or decreasing rainfall, either for the Indian region as a whole or for meteorological subdivisions of the country. Thus, in the Indian context, it is more pertinent to analyze impacts of climatic variability rather than of climatic change.

The variability of rainfall in India is predominantly interannual, between years with adequate rainfall and years of drought (defined in this case study as years with rainfall less than 75% of the mean (*see* Section 1). The amplitude of these interannual variations over the country as a whole is not very large: the standard deviation is about 10% of the mean and the worst drought of the century involved a deficit of only 25% of the mean. However, the total rainfall over the country is not the most useful index, because even in a year in which Indian rainfall is normal, many regions suffer from droughts and some from floods. Over smaller subregions the coefficient of variation is much larger than 10%, as much as 60% in arid regions. In addition to the variation in the total amount of rainfall received, the rainfall pattern (i.e., the distribution within the year) also varies considerably. The aim here is to develop a method for assessment of the impact of this variability in the amount and pattern of the monsoon rainfall on agricultural productivity.

Since the agricultural productivity of India as a whole is the sum total of production in the different agricultural zones, the impact of the variability of rainfall over each of these zones has to be assessed. Clearly, the first task is the identification of the agricultural zones. These can be characterized by homogeneity of the crop complex grown and can be determined by classification or cluster analysis of cropping patterns over a suitable network of observations. Alternatively, if the nature of the soil required and the optimal rainfall as well as

the tolerance range for each crop are known, the agricultural zones can be derived directly from an analysis of the spatial variation of the soil and rainfall.

If we assume that over historical time the traditional cropping pattern over any region has evolved so as to be the optimal pattern for the soil and climate (particularly the rainfall) of that region, then even in the absence of such detailed information about the climatic preferences and tolerance of the crops, it is possible to deduce the agricultural zones. Over a monsoonal region where there is considerable variation in the annual rainfall received as well in its distribution within the year, we can expect the cropping pattern to be the optimal one for the most probable amount and pattern of rainfall, i.e., the modes of the distributions of these two features. If the mode and mean coincide (as is found to be the case for both annual and monthly rainfall), the cropping pattern can be explained largely in terms of the climatological mean rainfall.

Regions over which the climatological mean rainfall patterns are similar will thus be characterized by similar cropping patterns, provided the soil is homogeneous. If we take climatic clusters to be regions that are homogeneous with respect to the interannual variation in the amount and pattern of rainfall, agroclimatic zones can be obtained by superposition of the climatic clusters on a soil map.

The impact of the variability of rainfall on the yield of an agricultural zone cannot be assessed by analysis of the mean rainfall over that zone because, although the mean rainfall pattern is similar over an agroclimatic zone, the rainfall variations are not necessarily coherent within each zone. In other words, in any given year only a part of the region may experience drought or an abnormal rainfall pattern. Thus, the impact of the variability of rainfall has to be assessed for coherent subregions within each agroclimatic zone.

Following a brief discussion of the nature of the rain-giving system and the spatial variation of rainfall, the climatic clusters of the Indian region, within each of which the mean annual rainfall and the rainfall patterns are similar, will be described. This provides some insight into the number of agroclimatic zones in the country. For the state of Karnataka, for which data on the cropping pattern are available for 175 subdivisions, the agricultural zones are derived using a clustering algorithm specially developed for the purpose. Focusing on an agroclimatic zone in the northern part of the state in the semi-arid zone that extends across the peninsula, a subregion over which rainfall variations are coherent has been identified. For this subregion, the impact of the variation of amount and pattern of rainfall is assessed qualitatively using available data on the yield of traditional varieties of the major crop grown (sorghum). The biological basis for the impact of rainfall variability, which is not considered in this approach, is dealt with in Section 3.

2.2. Monsoons, the ITCZ and the Spatial Variation of Rainfall

The monsoonal regions of the world are characterized by a seasonal migration of the equatorial trough or the intertropical convergence zone (ITCZ), which occurs