Use of Environmental Information Systems in Analyzing Crop Adaptation and Production Constraints as an Aid to On-farm Research

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Introduction

A focused research and development program for a crop or cropping system should be based on a comprehensive analysis of the relevant database for the target region. This database should comprise production and area trends, and factors affecting production including biotic, abiotic, socioeconomic, and utilization constraints. The information should be presented as clearly as possible in order that it may be adequately interpreted by a wide range of persons, including nonspecialists. The recent development of geographical information systems (CIS) —computer-based packages which allow rapid plotting of large data sets as digitized maps — is a great help in this area. GIS packages were originally developed for land-use planning to depict mainly geographical features such as soils, water courses, administrative boundaries, vegetation pattern, etc. However, for crop research it is also necessary to plot climatic factors, incidence and extent of biotic and abiotic constraints, and socioeconomic factors. Among researchers concerned with crop adaptation and interested in exploiting GIS technology, the terminology of 'environmental information systems' (EIS) is being increasingly used, as this more comprehensively describes what is plotted.

At ICRISAT, we had earlier attempted mapping production zones and production constraints of groundnut, chickpea, and pigeonpea crops in various Asian countries but without the aid of EIS. Results of this manual cartographic exercise are presented in an ICRISAT Research Bulletin (Virmani et al. 1991), which proved to be a useful base line of knowledge available up to the end of the 1980s. But it was a laborious and time-consuming exercise.

We therefore established an EIS facility. In a collaborative exercise between the International Center for Agricultural Research in Dry Areas (ICARDA) and ICRISAT, EIS is being used to plot out the factors affecting adaptation and production of chickpea in the West Asia and North Africa (WANA) region. We are thus in the process of adapting EIS to answer questions concerning crop adaptation.

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The purpose of this paper is to briefly describe the use and potential of EIS in understanding crop adaptation and in research prioritization. We are beginning an EIS study of adaptation of groundnut in Vietnam, which we will draw upon to illustrate the application of EIS to crop research and development.

Description of EIS

A landscape is composed of many components: land resource base, vegetation, man-made boundaries, climatic factors, etc. The advent of computers with large memories has allowed digitization of such data sets in the form of individual map layers by using EIS technology. Existing maps can be directly digitized on digitization boards, whereby boundaries are reproduced on the computer screen on the basis of grid points. Different map layers can be instantaneously superimposed so as to help in understanding better the relationships between them. This procedure can also be done by standard cartographic means but slowly, laboriously, and with a high probability of transcription errors.

The scale of the landscape may vary from global to farm size. For example, at ICRISAT we have been using global plots of crop distribution in relation to various factors to set research priorities for our mandate crops on a global basis. At the other extreme, we use an EIS system for database management of the ICRISAT research farm. But mostly we work at the level of a country, or a region within a country, to understand crop adaptation.

Use of EIS for Groundnut in Vietnam: a Case Study

Since 1976, the area, production, and yields of groundnut in Vietnam have shown an increasing trend (Fig. 1). To establish the primary production zones of the crop, we plotted the area distribution on a provincial basis (Fig. 2). In Vietnam, the number of provinces is sufficiently large so as to adequately delineate country-wide distribution of the crop. Greater precision can be achieved by plotting out district data' (e.g. for a portion of the country), but we first attempted a countrywide overview. There have been some changes in provincial boundaries in recent years and this complicates display of the time trends. Where changes have occurred, district-level data are required to accurately represent production changes over time. Figure 2 indicates where the increases in area have occurred between 1976 and 1990, mainly uniformly across the country. In 1976, groundnut yields were highest in some southern provinces. In 1990, yields generally increased in southern provinces and in the Red River Delta area in northern Vietnam (Fig. 3).

We are examining these production data in relation to various environmental factors (data are being assembled and digitized). For the information on soil, we will use the FAO-UNESCO soil map of the world. The major climatic factors to consider are soil-water status and temperature. For groundnut grown in seasons other than the

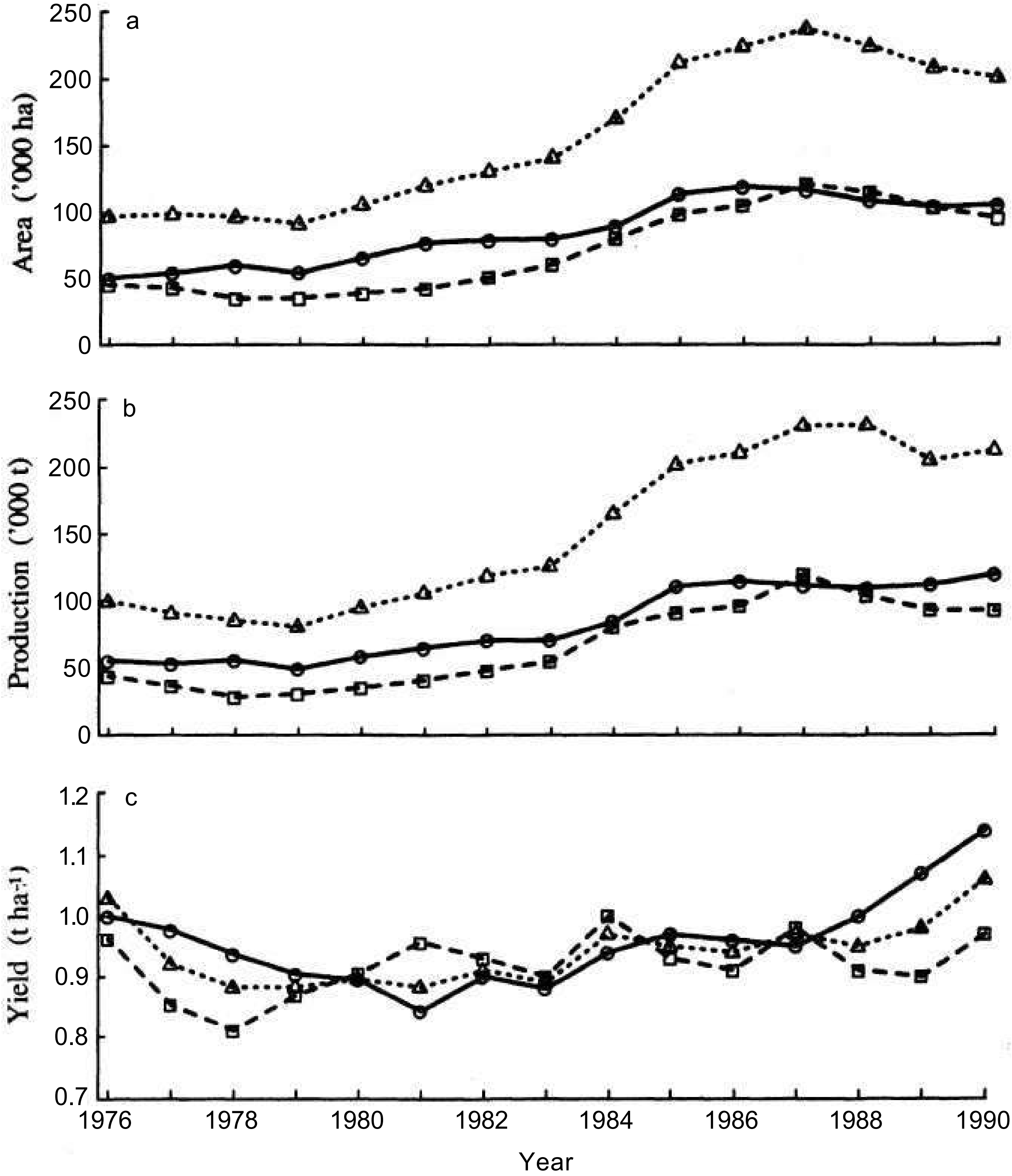

Figure 1. Trends in (a) area, (b) production, and (c) yield of groundnut in southern (o), northern (□), and total (Δ) Vietnam from 1976 to 1990.

rainy season, as is normally the situation in Vietnam, isohyets for total rainfall may not be of value in interpreting groundnut adaptation. It is thus necessary to establish and map the mean soil-water balance during the cropping season, based on rainfall, evapotranspiration, and soil-water holding capacity. Simple soil-water balance models are available for doing such an analysis. However, due to the variability in rainfall

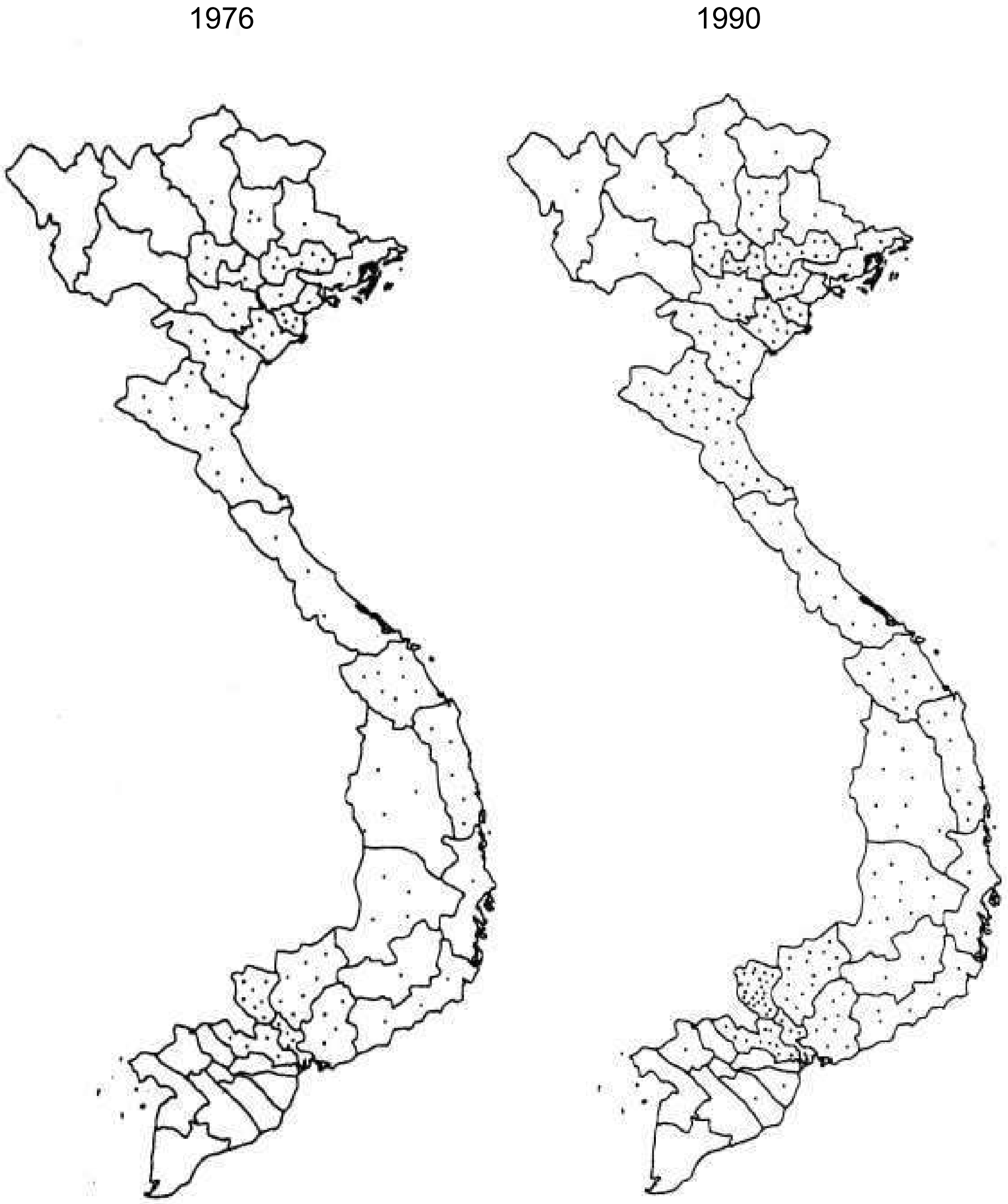

Figure 2. Area sown to groundnut in each province of Vietnam in 1976 and 1990. (Each dot represents 1000 ha.)

distribution between years, it would also be necessary to factor in probability values for available soil water at any particular time during the growing season. Probability analyses of the type used for rainfall data (Virmani et al. 1982) could be adapted to apply for available soil water. The challenge before, us is to incorporate such probability information into EIS plots. These types of analyses will help us to establish possible drought limitations and to identify genotypes and crop management practices that will alleviate the problem.

As waterlogging is at least as important a constraint as drought towards the end of the growing season in northern Vietnam and during the rainy season in southern Vietnam, it is also desirable to delineate probable incidence and extent of water-

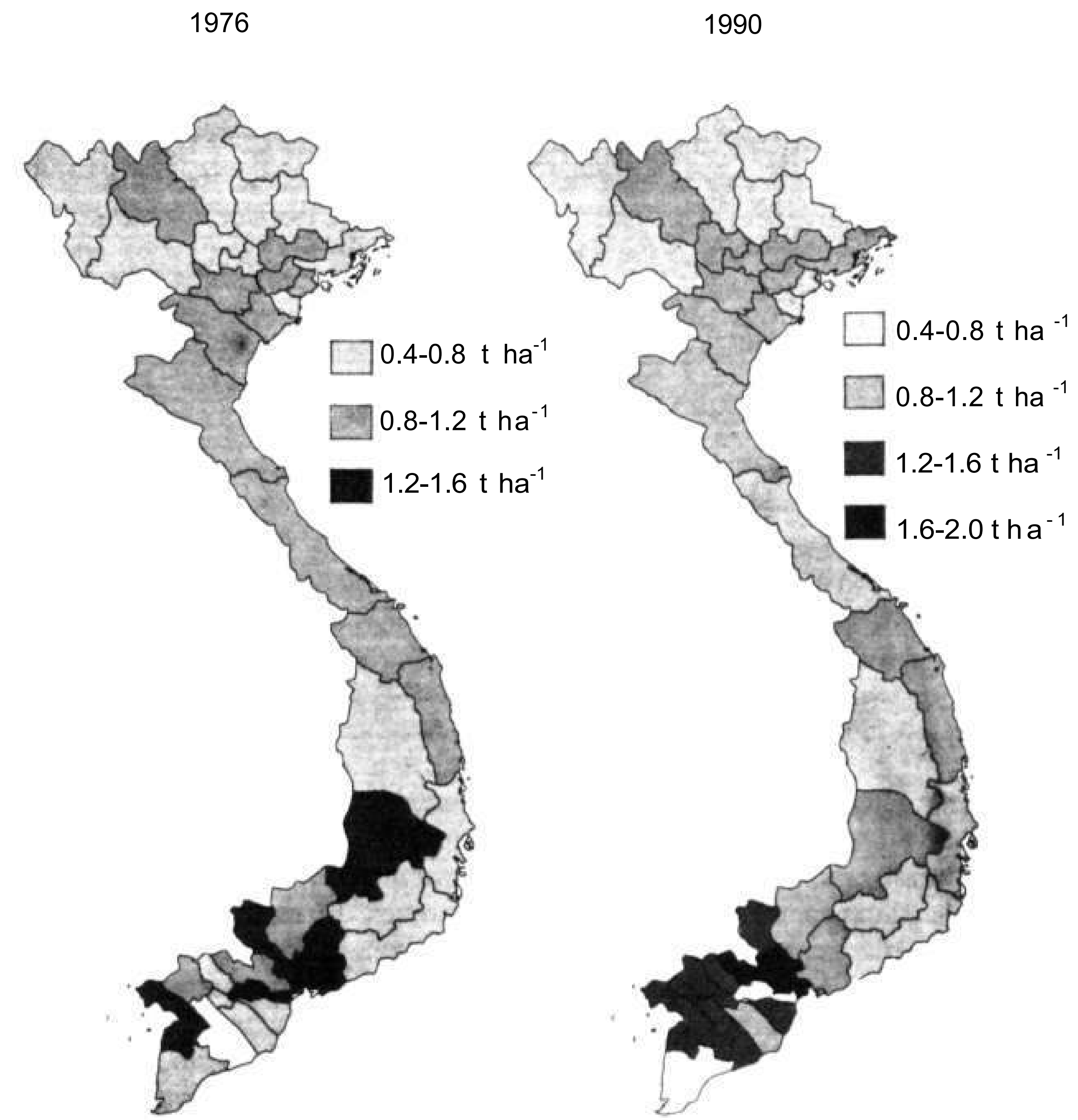

Figure 3. Groundnut yields in each province of Vietnam in 1976 and 1990.

logging damage. This may be done by calculating probability of incidence of rainfall on a fully charged soil profile.

We will also plot critical temperature isotherms that limit growth and yield of groundnut. Probability considerations will also apply to critical temperature plots, as discussed for available soil water. This information will guide us in genetic improvement of high or low temperature tolerance. There are also management options to overcome adverse temperature effects. For example, for low temperature stress at the establishment of the winter-spring crop in northern Vietnam, sowing of sprouted seed or use of polythene mulches covering the seed bed are available options.

We are also gathering information on pest and disease constraints to groundnut in Vietnam, which will be integrated into the EIS. We will examine how biotic constraints relate to various soil and climatic factors, by overlaying such databases, so as to gain insight into possible causal factors and control options. However, survey data for biotic stresses are generally incomplete, for any crop in any country. This is further complicated by seasonal changes in the pattern of pest and disease incidence. While we do not expect to be able to plot out biotic stresses in a comprehensive manner, we would recommend a more systematic method to record biotic stress data in a format compatible with EIS. This would require a uniform rating system to estimate the damage intensity or, preferably, extent of yield loss due to a particular biotic constraint.

Prospects for EIS in the Research and Development Process

EIS is proving to be a valuable tool in the research prioritization process, which is an improvement on the usual empirical way of deciding research priorities. Using EIS format to present research proposals for administrative/donor support is also seen as an advantage. EIS can be used to identify areas with potential for increased production of a crop, either by increases in yield or area under cultivation. It would thus guide us to site on-farm research trials for adapting improved technology.

EIS not only effectively displays current knowledge on crop constraints but also highlights gaps in that knowledge. It indicates where to direct surveys to obtain missing information. EIS provides both an incentive and a means (e.g., through standardized data entry format) for more comprehensive and regular surveys. This is a particularly important consideration for identifying and rating biotic constraints, about which there is usually limited information, especially regarding the distribution and fluctuation in incidence and severity over time.

EIS helps in better documentation, and attractive display of impact of research and development efforts. It can also display scenarios based on 'what if questions. It facilitates integration of the continuum: basic/applied/adaptive research—extension—adoption—impact. It thus allows on-farm research to be placed in perspective and provides a feedback mechanism among components of the continuum.

EIS technology should be adopted as soon as possible by national agricultural research systems (NARS) for their use as a planning tool for crop and agricultural systems improvement on a national scale. International agricultural research centers (IARC) have a role to play in facilitating adoption of EIS by NARS, by helping to identify financial support to establish EIS and by providing training in the technology. IARCs can also assist by ensuring linkage to existing digitized databases, to help design standardized database assembly systems, and to promote compatibility of databases. The involvement of NARS is basic for obtaining the necessary data for EIS, and NARS should take maximum advantage of using the resultant databases.

In summary, EIS should facilitate future:

- research efficiency,
- development of research domains, and
- development of application domains (where best to apply established technologies).

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