978 91 - 10/111

Plant protection
Review, tropics, millet, insect pests, management, soil pests, seedling pests, foliage pests, storage pests

GAHUKAR, R.T.

Insect pests of millets and their management: a review.

Tropical Pest Management, 35, 1989, pp. 382-391

Due to the increasing importance of millets in food production in developing countries, the pest situation is reviewed in this paper to facilitate improved pest management strategies.
The average grain yield is 300-500 kg/ha under traditional farming conditions. Millet improvement programmes are active in several countries and yields up to 2-3 tonnes have been obtained with intensive cultivation.
Approximately 85% of production is utilized for human food, 6% for seed and waste and 9% as cattle feed. In Africa, stalks are used for animal feed and for fencing and roofs of houses.
With the improvement in cultural practices and erratic rainfall in the tropics, new pests are introduced or the status of known pests altered. Some are common throughout millet growing areas but their economic importance differs considerably within seasons. Yield losses of 10-20% have been recorded in India.
About a hundred insect pests attack millets in the field and during storage. Some are common throughout the millet growing areas. Stem borers and grain midge are of regular occurrence. White grubs are important in India. Spike worms have recently become serious in the sub-Sahelian zone of West Africa. Sporadic attacks of blister beetles, armyworms, grasshoppers, chinch bugs, leaf beetles, head caterpillars and head bugs result in severe yield losses in certain seasons. There is a higher incidence of storage pests in the rainy season. Research on pest management needs to be intensified. The tactics differ with the pest complex and the agroecosystem. However, a combination of cultural practices and resistant cultivars have proved to be effective.
The problems faced by millet growers are different from those growing cash crops. Millets are a major source of subsistence and inputs of production are often minimal, and benefits are marginal under traditional farming conditions. Information is needed, particularly on the standardization of screening techniques, resistance mechanisms, insect rearing, the termination of summer diapause, yield loss estimation, the establishment of economic injury levels, the effectiveness of natural enemies and their use in existing ecosystems. Newly introduced plant material,

particularly hybrids, are susceptible to several species. Emphasis should therefore be placed on multipest resistance. The traits responsible for resistance must be incorporated into agronomically suitable cultivars. This will reduce the use of insecticides and make acceptance of recommended practices by farmers easier.
Collaboration should encourage an interdisciplinary approach to pest management through the exchange of genetic material and research information.

979 91 - 10/112

Plant protection
Latin America, Peru, lowlands, weed control, weed population, dynamics, weed species, cropping systems, shifting cultivation, rice, soybean, maize, crabgrass, goosegrass, itchgrass, fallow period, socio-economy, herbicides, fertilization, tillage practices

PLEASANT, J. Mt. et al.

Weed population dynamics and weed control in the Peruvian Amazon.

Agron. J., 82, 1990, pp. 102-112

This experiment had the objectives to identify weed species resistant to the herbicide program in a continuous-cropping system, and develop effective weed management practices for intensively managed cropping systems in the humid tropics.
The study was initiated at the Yurimaguas Res Stn. in Eastern Peru on a fine-loamy, siliceous soil. Mean annual temperature at Yurimaguas is 26°C with little monthly or daily variation. Average annual precipitation is 2250 mm. There is a distinct dry season from June through August.
The Yurimaguas environment permits three harvests per year (three biological cycles) if short-cycle food crops are used.
The experimental design was a split plot. Four weed control treatments applied to rice represented the main plot treatments. Split-plot treatments were five weed control treatments on corn and soybean.
Population pressure in Peru, along with the country's desire to increase its agricultural base, requires alternatives to shifting cultivation. Successful continuous cropping systems, which eliminate the fallow period, will depend on soil fertility management and effective weed control.
Labour for hand weeding in the Peruvian Amazon Basin is a major impediment to increasing agricultural production; it is largely unavailable at any price. The use of herbicides, on the other hand, presents special problems.
Upland rice, which is particularly vulnerable to weed pressure, appears to be an inappropriate crop if the difference between weed control costs and crop value is considered. The greater competitive abilities of corn and soybean suggest that lower rates of herbicides in these crops can provide weed control that is both effective and economic.
Concluding the authors state:

- The spectrum of weed species in the field changed dramatically over the course of the experiment. Large crabgrass-plus-goosegrass was the most important weed problem in the first three crops of the experiment. At the conclusion of the study itchgrass dominated the site.

- Changes in the weed population were attributable to the weed control treatments employed.
- All herbicides were effective in controlling sedges but even when no herbicide was applied, sedges disappeared after the first crop.
- Residual effects of weed control treatments on subsequent crops were measured, although these effects generally disappeared after two crops. Large weed populations in one crop often resulted in more weeds and decreased crop yields in the next crop regardless of the weed control treatment used. In particular, failure to control itchgrass in one crop dramatically increased its level of infestation and ability to reduce yields in the next. At the end of the experiment, treatments which had received only metolachlor in both corn and soybean had weed populations with 97% itchgrass.
- Tillage had large effects on the level of weed infestation, population composition, and crop yields. In most instances, weed infestations were higher and crop yields lower under no-till management. Grasses were predominant under no-till conditions, but dayflower grew more readily when the filed was tilled. When no-till followed no-till, perennial grasses increased.
- The three crop species differed greatly in their ability to compete with weeds. The order of competitiveness was corn > soybean > rice.
- An effective weed control program for intensively managed crops in this region is possible, but it may not be economical. Costs for the different weed control treatments ranged from \$50 for one weeding by hand to \$185 ha^{-1} for the chemical treatment.

980 91 - 10/113

Plant protection
Review, booklet, pest control, pest poisoning, synthetic pesticides, biological pest control, biotechnological pest control, agronomic practices, integrated pest management, traditional cultivation methods, institutions, organizations

PAN

Fighting pests the natural way.

Publ. of Pesticides Action Network (PAN-Europe), Damrak 83-1, 1012 LN Amsterdam, The Netherlands; 1988, 46 p., price DF 18, USD 4

According to recent estimates by the World Health Organization, approximately one million people are taken ill every year with pesticide poisoning. Some 20,000 die in agony. There is also an ever-growing threat of irreversible damage to the environment - soil, water, air, flora and fauna - because of pesticides.
In the industrialized countries there is a slowly-growing awareness of these problems, but in the developing world most of the attention is still geared to famine prevention. It is now recognized that this will be achieved not so much by concentrating on yield increases as by long-term safeguarding of natural resources such as soil and water and by the maintenance of a natural balance between such resources and the plants and animals which thrive on them.
The Pesticides Action Network (PAN-Europe) has produced a report which is an introduction to the protection of plants without synthetic pesticides. Fighting Pests the Natural Way aims to give an insight into natural pest control, especially in developing countries, and so contribute to the development of a form of agriculture which could supply future generations with food without destroying the natural environment.
Biological, biotechnological, and physical methods of control are outlined, as well as the importance of crop rotation, soil tillage and field hygiene.
The book explains how to produce easy-to-make, low-cost pesticide sprays based on protective substances occurring in plants. Integrated Pest Management (IPM) and locally adapted cultivation methods are also discussed.
The booklet includes a list of institutions and organizations which can give further information. It should be read as a source of suggestions and proposals for action concerning plant protection which will not be harmful to the environment.
Abstract from SPORE

981 91 - 10/114

Plant protection
Review, book, Africa, sustainability, crop pests, biological control, integrated pest management, systems management, economics of pest control, IITA

YANINEK, J.S. and H.R. HERREN

Biological control: a sustainable solution to crop pest problems in Africa.

Proc. of the Inaugural Conference and Workshop of the IITA Biol. Control Program Center for Africa; Cotonou, Benin, 1989, 203 p.

On way to stabilize and increase production is to protect crops from the pests and weeds that are ever-present in these agroecosystems. However, crop protection can have adverse economic, environmental, and health consequences if inappropriate control measures are used. Agroecosystem management based on a thorough knowledge of the key biological interactions, such as the use of biological control for plant protection, will have a comparative advantage over the long-term.
Although classical biological control was used in the cassava mealybug case, the underlying research philosophy of the Biological Control Program of IITA is to identify the ecological imbalances in the system causing a pest problem and provide the appropriate solution. "Pests" are carefully evaluated for their real pest status before extensive research and control campaigns are initiated.
Biological control comprises the use of living natural enemies as pest control agents, and it includes the introduction of exotic beneficial organisms, the augmentation of natural enemies to increase their effectiveness, and measures to enhance the action of beneficial species already present in the agroecosystems. In the following recommendations, the term "pest" refers to all categories of noxious organisms, including animals, pathogens, and weeds.
A workshop held recommended amongst others:
- that biological control research programs be set up for the pests deemed a priority by national program delegates and supported by donors and international institutes. The highest priority is perceived as the development of alternatives to chemical control for the desert locust. High priority is also given to the establishment of programs against the larger grain borer, cereal stem borers, water hyacinth, and witch weed. Biological control of vegetable pests, whitefly, and siam weed should also be considered.
- that, as knowledge of the African fauna and flora is limited, provision be made for taxonomic research in requests to donors for funding of biological control activities.

- that methods used to assess the field impact of natural enemies released against a target host be standardized as far as possible to allow for results obtained in the different countries to be adequately compared.
- that, in view of the problems involved in transferring and maintaining colonies of natural enemies in decentralized rearing units, mass-rearing should be concentrated initially in regional centers, while new technologies to increase the efficiency of rearing systems are developed.
- that, on behalf of the African plant quarantine and plant protection services concerned, the global International Organization for Biological Control asks FAO to organize appropriate consultations to define guidelines regulating the transfer and release of natural enemies used for classical biological control.

982

91 - 10/115

Plant protection
Review, book, study, tropics, sub-tropics, weed management, small-scale agriculture, weed plant, weed control, agro-ecology, socio-economy, weed control methods, research needs

ALSTRÖM, S.

Fundamentals of weed management in hot climate peasant agriculture.

Publ. of Departm. of Crop Production Science, Swedish Univ. of Agricultural Sciences, P.O.B. 7043, 75007 Uppsala, Sweden; ISBN 91-576-4403-9, 1990, 271 p.

The consequences of different strategies of weed management under resource-poor small farm conditions are discussed in this study. Major aspects included are weed biology, agro-ecology, economics and social welfare. References are made to experimental results in several parts of the Third World tropics with emphasis on Indian agriculture.
Plant population behaviour is discussed in an agro-ecological context in which crop plants, weeds and useful non-crop plants are viewed as interacting components of site-specific cultivation systems.
Certain established views prevailing in weed science literature are critically examined. One of these refers to the competitive effect of weeds on crop yield at low weed plant density.
The importance of an all-round understanding of the consequences of introducing inputs with strong social and ecological impacts is stressed upon. It refers to the use of several herbicides which at present increase rapidly in many commercially advanced regions of the Third World including parts of India. The overall consumption of chemicals in tropical weed control is still relatively small, however, especially in less well endowed regions.
A major part of this study deals with non-chemical weed management methods. Case studies highlighting the social aspects of weeding in rural India have been included. The importance of harnessing farmer experience in developing weed management systems is emphasized.
Author's summary.

983 91 - 10/116

Plant protection
Review, biological pest control, evaluation of methods, experiments, models, surveys, practical problems, IITA

NEUENSCHWANDER, P. and A.P. GUTIERREZ

Evaluating the impact of biological control measures.

In: Proc. of an IITA Workshop, Cotonou, Peoples Rep. of Benin, 1989, pp. 147-155

Impact assessment of exotic biological control agents is essential for understanding and for attributing benefits.
For use in Africa, the classical methodologies often need to be reevaluated because of the agricultural heterogeneity found on subsistence farms. Most studies assess impact of introduced or indigenous beneficials on pest populations only. The ultimate test of benefit is, however, to measure yield loss reduction due to a natural enemy.
Man introduces artificial components into the system via breeding, cultural, and chemical interaction.
In the classical definition of IPM, developed for intensively manipulated systems with an important, already existing component of pesticide applications, chemical and cultural control, resistance breeding, and biological control are four additive, conceptually equal components.
Before a quantitative estimate of impact is needed, it is often important to know whether biological control is of any significance at all in the particular agricultural system. In such pilot projects, exclusion experiments offer a first approximation. Though they introduce artificial conditions, they remain a convincing way to demonstrate that beneficial organisms exist and can reduce the pest populations.
Exclusion experiments are difficult to handle, but it is felt that they help to focus research and to indicate whether further ecological studies are required. This is particularly true in pilot projects where the existence of biological control through indigenous natural enemies in some ecological situations is suspected. As it happens, chemical exclusion experiments are often performed involuntarily when insecticides are misused. The resulting secondary pest outbreaks then point to the presence of previously existing natural enemies whose role had not been known or appreciated.
In repeated surveys of agricultural systems, the spatial and seasonal variations of pest and natural enemy populations are described and associated with differences in abiotic and biotic factors. The data are quantitative spot estimates of dynamic processes, with additional qualitative inputs. They are useful for statistical analyses where the resultant relationships can be inferred from prior biological data or intuition, but do not give explanations for possible cause-effect relationships.

Population dynamics studies assess changes in population densities in time and are, for practical reasons, often very limited in space, covering only a few combinations of abiotic and biotic factors.
A better understanding of the mechanisms governing population dynamics of the pest and its natural enemies requires the assessment of plant characters. Since population dynamics studies are entirely descriptive showing only the time evolution of the interactions, but not the causes for the observed dynamics, these causes have to be evaluated experimentally.
Life-table studies in the laboratory under different constant conditions estimate the respective maximum intrinsic parameters, while age-specific life-table studies conducted in the field estimate the impact of the different factors at a particular time.
A fruitful approach, especially for species with overlapping generations, is the development of simulation models. In such models, the measurement of resource acquisition and allocation leads to realistic estimates of birthdeath rates.
Such models can be used to simulate the effects of weather on the host plant, the pest, the natural enemy, and their interactions.
For a satisfactory assessment of natural enemy impact, several of the above methods need to be applied. All methods have severe drawbacks. The frequent lack of impact assessment is the reason biological control has often remained more of an art than a science.
But with the right conceptual framework, impact assessment becomes the most important scientific activity supporting the practice of biological control.

984 91 - 10/117

Plant protection
Africa, Cameroon, study, crop protection, smallholder participation, agronomic practices, traditional methods, extension, IFOAM, NGO's

SCHRIMPF, B.

Natural crop protection an approach in participation with smallholders in Cameroon.

In: Proc. of 7th IFOAM Int. Sc. Conf., Ouagadougou, 1989, pp. 359-367

The aim of this paper is to outline the testing of natural crop protection methods suitable for smallholders in the Bamenda Grassfields, Cameroon.
In a first phase such methods were tried out together with the trainees of the Rural Training Center with good success. Especially pests in the garden could be effectively controlled with sprays made out of garlic and hot pepper. These good results with effective but inexpensive natural insecticides led to questions whether other natural methods which are more adapted are practised by smallholders in the area.
The different ethnic groups (in the Bamenda Grassfields are more than 50 different tribes) are still using many indigenous methods to protect their crops. But these methods and the indigenous knowledge are more and more disappearing and no longer valued by many smallholders. They are looked upon as methods from the parents which are outdated and backwards, and which have to be replaced by modern methods - western technology based agriculture with high external inputs. This is an important reason why traditional experience and indigenous methods are vanishing.
Against this background, two seminars of one week duration each were organized with smallholders and extension workers on "natural crop protection".
A wide variety of local plants was traditionally used to be effective against pests.
Plants so far botanically identified are:

Lobelia columnaris	used against stemborers in maize
Stirchnos aculeata	fish poison, used to treat yam sets in combination with wood ash
Tephrosia vogelii	fish poison, used in storage
Erythrophleum sp.	the bark is burned and used as a fumigant in storage

Ricinus sp.	reported to be beneficial when intercropped, insecticidal spray
Aframomum sp.	reported to prevent stemborer attack in maize
Nicotiana tabacum	insecticidal spray
Lantana sp.	used in storage
Echinops longifolius	protects store houses from rodents
Chenopodium ambrosoides	used in storage and as repellent against termites

985 91 - 10/118

Plant protection
Review, book, crop protection agents, controlled release formulation, chemical pest control, biological control, biopesticides

WILKENS, R.M.

Controlled delivery of crop protection agents.

Publ. of Taylor and Francis, UK, ISBN 0-85066-739-9, 1990

This book is a collection of 15 chapters, written by some of the major protagonists of the development of various types of controlled release (CR) formulations of pesticides. Part I (Introduction) contains 3 chapters, the first displaying a rather tenuous link between spraying and CR but with cautionary statements such as' making pesticides last longer may not necessarily be the most appropriate research strategy'. Chapter 2 is an excellent review of soil/crop-protection agent interactions, but only the last two pages deal with the physical properties of crop protection agents (cpa) that 'may benefit from CR'. Disappointingly from a Monsanto author, there was nothing on one of the larger current cpa CR soil products, Lasso Micro Tech. Chapter 3 provides a good overview of CR systems and contains the first data demonstrating greater efficacy of CR products over conventional formulations. Unfortunately this was against cockroaches in an apartment rather than for a cpa in a crop situation.
Part II (Controlled Delivery of Sprayable Systems) contains three chapters on micro-encapsulation which, between them, provide a comprehensive coverage of the topic though, inevitably, with some overlap. Methods of preparation, advantages and limitations of micro-encapsulation are well discussed.
Part III contains two chapters on Granular Systems and Soil Applications. Chapter 7 is an article from Incitec International on their efforts to use monolithic polyethylene CR (suSCon) granules incorporating the less persistent organophosphate and organocarbamate insecticides as replacements for the now unavailable, more persistent and effective, organochlorine insecticides in controlling primarily soil pests of sugarcane and tree plantations. Chapter 8 reviews the use of lignin-based CR formulations in soil and rice paddies. Part IV (Release into Air) has a single chapter on CR systems for insect pheromones. Part V (Release into Water) discusses all the approaches to CR in aquatic applications and states that 'the value of CR formulations allows treatments to be localized, rather than spraying large areas, and thus reducing peak concentrations and quantities... placement may be as important as the rate of release'.
There are three chapters in Part IV, Controlled Delivery of Biopesticides. These make it clear that the use of microbial pesticides on a commercial basis is still in its infancy but that one of the early problems to be recognized was the need for good

protection and delivery systems at the right time and place. Problems and some solutions, in other host micro-organisms, are discussed.
There are two final chapters in Part VII, on Evaluation of CR Systems. The first of these is an overview of CR, while the final chapter gives useful examples of chemical and biological evaluation of CR formulations in laboratory and field tests and places the CR approach into perspective. The 1981 Wood Mackenzie report No 19 estimated that CR applications accounted for - 0.5% of pesticide application. Current estimates place this nearer to 2%. An appendix listing 70 'Established controlled-delivery formulations' is useful though it quotes products that never became commercial or have now been withdrawn.
An objective read of this book will help to focus the mind of anyone contemplating a CR project and would be time well spent before launching into a programme that will inevitably burgeon but, like many others before it, may never achieve that elusive goal of cost-effective performance under field conditions.
Abstract by T. Grayson.

986 91 - 10/119

Plant protection
Africa, Ghana, Ivory Coast, survey, biological pest control, impact assessment, cassava mealybug, farmer's fields, cassava

NEUENSCHWANDER, P. et al.

Impact assessment of the biological control of the cassava mealybug, *Phenacoccus manihoti* **Matile-Ferrero (Hemiptera: Pseudococcidae), by the introduced parasitoid** *Epidinocarsis lopezi* **(De Santis) Hymenoptera: Enrcyrtidae).**

Bull. ent. Res., 79, 1989, pp. 579-594

In the early 1970s, the mealybug *Phenacoccus manihoti* Matile-Ferrero was accidentally introduced from South America to Africa where it spread and became the major cassava pest.
The objectives of the paper therefore is to assess the impact of *P. manihoti* on tuber yields at the farm level over a wide range of conditions and to measure the effects of the introduction of *E. lopezi* on *P. manihoti* and tuber yield. A description of individual biotic factors is followed by a multiple regression analysis assessing the relative importance of biotic and abiotic factors, and summed up by a general production function for cassava tubers.
In a large-scale biological control project against this pest, the solitary, host-specific parasitoid *Epidinocarsis lopezi* (De Santis) was imported from South America and first released in Nigeria in 1981. By July 1988, it had been successfully established in 19 African countries and had spread over an area of over 1-5 million km². Regular monitoring in two areas in Nigeria showed that *P. manihoti* populations declined after the releases of the exotic parasitoid and remained low. Large-scale surveys in south-western Nigeria and exclusion experiments also documented the efficiency of *E. lopezi* in preventing *P. manihoti* outbreaks in most fields. A computer simulation model for the growth of cassava predicted that E. lopezi is capable of preventing tuber yield losses, while the impact of the native coccinellids in suppressing *P. manihoti* populations is small.
In this study twenty-nine variables associated with plant growth, agronomic and environmental factors, and insect populations were recorded. Densities of *P. manihoti* were closely correlated with stunting of the cassava shoot tips and, less so, with the rate of stunting early in the growing season. With increasing mealybug infestations, average harvest indices declined and populations of *E. lopezi* and of indigenous coccinellids increased, but parasitoids were found at lower host levels than were predators. The length of time *E. lopezi* had been present in an area was the most important factor influencing mealybug densities. Thus, *P. manihoti* populations were significantly lower where *E. lopezi* had been present for more than half the planting season than in areas where *E. lopezi* was lacking or had been only recently introduced. A significant proportion of the farmers in the savanna zone, where *P. manihoti* populations were much higher than in the forest zone,

had observed this decline due to *E. lopezi*. Tuber yield losses due to *P. manihoti* in the absence of *E. lopezi* were tentatively estimated at 463 g/plant in the savanna zone. No significant effect was found in the forest region.
The main contribution of the present study lies in the direct demonstration of the impact of *E. lopezi* on *P. manihoti* under the conditions of subsistence agriculture. As in other mealybug systems, ants played an important role. They are first attracted by the mealybug and then protect it against parasitoids and predators, almost exclusively coccinellids. The attraction of coccinellids and *E. lopezi* to the mealybug, i.e. the food supply, explains the positive relationship between *P. manihoti* and beneficial arthropods. *E. lopezi* was attracted to the mealybug even at the lowest host densities and reacted strongly to an increase in host density, whereas coccinellids arrived only later on the growing *P. manihoti* populations and reacted only weakly to changes in their densities. This difference between parasitoids and predators is commonly observed in homopteran systems.
The beneficial impact of the introduced biological control agent, *E. lopezi* was estimated as an increase in yield of 228 g/plant in the savanna zone, i.e. at roughly 2.48 t/ha. This constitutes a 50% loss reduction which can be used for estimating the global impact of this biological control programme, thereby replacing subjective assessments.
The interviews revealed that the farmers in the savanna zone were aware of the reduction in *P. manihoti* following the establishment of *E. lopezi*, of which they knew nothing. All farmers attributed the decline of the mealybug to higher rainfall during the rainy part of the 1985 cassava season.
The present data, which are unique in biological control, show that, in 1986, the difference in *P. manihoti* populations between eastern Ghana and central Ivory Coast under equally favourable rain patterns was attributable to the establishment of *E. lopezi*.

987 91 - 10/120

Plant protection
Review, agriculture, termite control, forestry, non-chemical methods, cultural methods, plant vigour, biological control, predators, pathogens, plant insecticides, wood ash, repellent material, plant resistance, physical barriers

LOGAN, J.W.M. et al.

Termite (Isoptera) control in agriculture and forestry by non-chemical methods: a review.

Bull. ent. Res., 80, 1990, pp. 309-330

Published information on non-chemical control is widely scattered in the literature.
There have been few adequate trials and there are conflicting views on the efficacy of the various techniques, which are often based on long established local practice.
This review brings together much of this information and assesses the potential of the various methods.
Termite attack on field and tree crops and on forestry trees, especially in the semi-arid and sub-humid tropics, causes significant yield losses and is often a major constraint on reforestation. Control in agriculture and forestry has relied almost exclusively on persistent organochlorine insecticides.
These chemicals, when placed as a barrier in the soil (e.g. seed dressing, planting hole or furrow treatments), can provide protection throughout the growing season for annual crops or longer for perennial and tree crops and forestry. Prior to the use of cyclodienes, highly toxic chemicals such as Paris Green and arsenates were used.
Because of increased environmental awareness demanding reduction in the use of commercial pesticides, there is renewed interest in non-chemical control of termites. In this review the use of locally produced plant derivatives are included, defining non-chemical control as those measures which do not use commercially produced pesticides.
Numerous cultural procedures have been suggested, including measures to enhance plant vigour, to manipulate termite numbers and behaviour, and others whose mode of action is unclear. Many are simply part of good agricultural/silvicultural practice and to be recommended. Biological control by predators or pathogens is unlikely to be successful due to the termites' social structure and behavioural responses to infected individuals and to loss of individuals to predators. The use of 'natural' insecticides from locally available plant products may be effective in some cases but, as they are not subject to the same rigorous safety and environmental evaluation as commercial pesticides, their use cannot be sanctioned unconditionally. Other locally available

products, e.g. wood ash, have not been adequately evaluated. Removal of reproductives from the nest and construction of physical barriers may have limited applications, but resistant species and varieties, combined with appropriate cultural methods and, perhaps, minimal use of modern pesticides in an integrated approach, offer the greatest potential for a long-term solution. The lack of critical scientific evaluation of non-chemical control makes it a field wide open for research.

XI WATER MANAGEMENT

988 91 - 11/35

Water management
Study, semi-arid tropics, Asia, Africa, Latin America, water harvesting, rainfall collection, watershed-based systems, water conservation, water utilization, contour bunding, soil loss, runoff collection, irrigation, costs and benefits, CAB, ICRISAT

KRANTZ, B.A.

Rainfall collection and utilization in the semi-arid tropics.

In: Proc. of a Workshop on Rainfall Collection for Agriculture in Arid and Semiarid Regions, CAB, UK, 1981, pp. 53-59

The purpose of this paper is to discuss the characteristics of rainfall and soils in relation to water intake, runoff, and erosion in order to better understand the management requirements of farming systems and thus increase the level and stability of production while conserving natural resources.
The Semi-Arid Tropics (SAT), where precipitation exceeds potential evapotranspiration for about 2 months to 4.5 months per year, has a diversity of soils, climates, and people. The area is home to about 600 million people, is characterized by soils low in organic matter (0.5-0.8%) and fertility and by undependable rainfall. Under these conditions, rainfed agriculture has failed to provide even the minimum food requirement for the rapidly increasing populations of many developing countries in the SAT.
In most regions of the SAT, the average annual rainfall would appear to be sufficient for one or in many cases two good crops per year. Rainfall patterns are erratic and undependable, with frequent rainless periodes even within the rainy season.
Alfisols (red soils) are the major soil order on each of the three continents in the SAT zone. They cover 32%, 34%, and 28% of the respective SAT regions of Africa, Latin America, and Asia. Alfisols and Vertisols (black soils) combined comprise 63% of the Asian SAT. Although Alfisols and Vertisols can occur in close association, their management requirements are distinctly different. The most striking example of this fact is the farmers' practice of planting crops in Alfisols only during the rainy season and in deep Vertisols only during the postrainy season. Management requirements are related to differences in type and amount of clay, workability, moisture-holding capacity, and other associated characteristics.
The primary constraint to agricultural development in the seasonally dry tropics is the lack of suitable technology for soil-and-water management and viable crop-production systems.
Summarizing the important results of this study, the following can be said:
Runoff from crop watersheds, collected in small reservoirs, was effectively used as supplemental irrigation on rainfed crops in

these watersheds. The broadbed-and-furrow system reduced erosion, improved crop drainage and facilitated supplemental irrigation, and cultural operations. Improved farming systems, tested for 7 years in operational-scale research watersheds, resulted in less erosion and a 4-fold increase of crop yields over traditional systems.

989 91 - 11/36

Water management
USA, Latin America, Mexico, study, reservation, water harvesting, floodwater farming, traditional cultivation practices, future prospects, CAB

BILLY, B.

Water harvesting for dryland and floodwater farming on the Navajo Indian Reservation.

In: Proc. of a Workshop on Rainfall Collection for Agriculture in Arid and Semiarid Regions, CAB, 1981, pp. 3-7

In olden times, Navajos planted crops according to star and moon cycles. Native seeds, collected from previous harvests, were used in the plantings. Corn seeds were soaked overnight in water and were planted from 2 to 8 feet apart in rows. Or the corn was planted in a circular pattern, starting from the center and going around and around until the field was done. The squash and melons were usually planted in rows. Navajos - instead of plowing their fields - used only a planting stick to break through dry-surface crusts to moist soil. With sticks, they made small holes 6 inches to 8 inches deep into which seeds were placed. Pressing moist soil down firmly on the seeds and placing dry soil on top, farmers made small depressions to catch the rains.
Today, with the assistance of federal, state and tribal funds, the tribe is maintaining modern sprinkler systems on the large Navajo Indian Irrigation Project and furrow-and-border irrigation systems on some 60-plus small-family farms scattered across the reservation. The other two types of farming methods are dryland and floodwater farming.
The most successful dry-farming zone lies principally in the humid belt on fertile soils. The short growing season found at this high elevation limits production. The second most favorable dry-farming area has moderately productive soils and falls within a 12-inch to 16-inch rainfall zone. Dryland and floodwater farming are practiced extensively within this zone. The rest of the reservation is generally unfavorable to farming of limited amounts of water.
Many farmers, particularly those around larger settlements, have access to modern plowing equipment. However, much farming is still done by families and this by hand. Like their ancestors, these Navajos use shovels and picks to dig 6-inch to 8-inch holes that hold 5 to 10 seeds each.
In general, successful Navajo dryland and floodwater farming depend on slopes, time of rainfall, and growing seasons. They also depend upon the use of rain harvesting technology, planting sticks, drought-tolerant species, and long-shooted seedlings, ones that can grow through 6 inches or more of topsoil. Older Navajos cite examples of corn seedlings that grew from a 1-ft depth to the surface.

Dryland and floodwater farming are alternatives to irrigation farming. But their continuance depends on Navajos retaining traditional cultural practices, doing more research on plant genetics and cultural practices, implementing the known water-harvesting technologies on small subsistance farms, and educating the people about agricultural resources and their development.

990

91 - 11/37

Water management
Latin America, Mexico, arid and semiarid areas, study, range seeding, water catchment practices, contour barriers, contour furrows, land imprinting, CAB

FIERRO, L.C.

Water-catchment practices for range seeding in the arid and semiarid areas of northern Mexico.

In: Proc. of a Workshop on Rainfall Collection for Agriculture in Arid and Semiarid Regions, CAB, 1981, pp. 87-91

In this paper the uses and effectiveness of soil treatments/water-catchment practices for seeding the arid and semiarid ranges of Mexico including large-scale applications of them, are discussed.
The arid and semiarid zones of Mexico's rangelands, covering more than 40% of the 2 million sq km of Mexico, are vital watersheds and important grazing lands for livestock production. Crop farming with dry-farming technology is not economically successful except at occasional favorable sites and in the few areas where irrigation has been developed.
Desirable grazing vegetation in most of the rangelands has been severely depleted by overgrazing that started in the middle of the 16th century, when the Spanish conquerors introduced domestic European livestock into Mexico. Natural recovery for many of these areas is slow to non-existent. Seeding may be the only hope to rehabilitate and to control erosion on these ranges.
Range-condition evaluations indicate that seeding is probably the only range-improvement practice that could increase productivity while preserving the soils and watersheds. One major limitation to seeding these zones is the lack of moisture during establishment. One way to overcome this is to prepare seedbeds properly and to build adequate water catchments that retain water until it infiltrates the soil, thus preventing runoff and soil erosion.
Water-catchment practices for range seeding are being evaluated at various research centers of Mexico. The main practices are contour barriers, contour furrows, pitting, ripping, and land imprinting. These mechanical soil treatments, if preceded by partial-to-complete seedbed preparation, could provide effective means of establishing range seedings.
Concluding, it can be said that a considerable number of technologies for seeding rangelands are available, most of which are adequate for large-scale applications. However, more research is needed to evaluate new methods, or combinations of methods, for grass-and shrub seedings, and more specialized equipment needs to be developed. Revegetating extensive areas of arid and semiarid rangelands in Mexico, so important in improving livestock production and protecting vital watersheds, can be achieved only through the use of proper water-catchment practices.

991

91 - 11/38

Water management
Asia, Israel, Negev Desert, study, saline water irrigation, crop salt tolerance, salt resistance mechanisms, management practices, breeding, sand dunes, salinity, DSE

CINADCO

Saline water irrigation in the Negev Desert.

In: Proc. of a German/Israel/Paraguayan Workshop on Agricultural Production under Semi-Arid Conditions with special reference to the Paraguayan Chaco, Shefayim, Israel, 1988, pp. 108-134

This paper describes the evolution of a complex research and development programme aimed at the utilization of saline water to irrigate new desert areas.
To maintain the present area of irrigated land, Israel has been learning to utilize alternative water sources for irrigation. The two main additional sources are reclaimed sewage water and saline water.
Physically, the Negev desert is ideal for the practice of saline water irrigation, for the following reasons:
- There are no significant freshwater aquifers that could be contaminated by saline drainage water.
- The desert has a very good natural system of wadis which drain into the Mediterranean Sea.
- The soil is rich in calcium, which neutralizes to a great extent the damaging effects of excess sodium (a major cation in most saline waters) on the soil structure.
- And finally, the bulk of the saline water in the Negev has a relatively low sodium/calcium ratio and therefore does not impose a potential sodium hazard on the soils.

In this paper the experiences, the merits and limitations of various aspects of the art of saline water irrigation, and present new avenues for further development are summarized. This paper is divided into seven sections:
- description of the soil, water and climate of the study area;
- crop salt tolerance;
- salt resistance mechanisms operating in the field;
- soil and water management;
- selection and production of salt-resistant cultivars;
- irrigation of sand dunes with saline water, and
- beneficial effects of saline water.

Today crops and technologies that will allow agricultural production with water containing up to 4,000 ppm salts (10% seawater) can be recommended. In the future, water of even higher salinity will be put to use, thus opening new horizons for saline water-based agriculture in desert of the Middle East and throughout the world.
A list of publications on salinity is given as references.

992 91 - 11/39

Water management
Africa, Botswana, field trials, soil moisture conservation, crop sequence, fallow system, ICARDA

JONES, M.J. and J. SINCLAIR

Effects of bare fallowing, previous crop and time of ploughing on soil moisture conservation in Botswana.

Trop. Agric. (Trinidad), 66, 1, 1989, pp. 54-60

The available water present in the soil profile at planting time is often a major factor determining the survival and yield of annual crops in regions of low and erratic rainfall.
The purpose of the work described here was to try to identify management practices for soil-water conservation less radical but more acceptable than whole-year bare fallowing. Comparisons were made between whole-year and part-year fallows and between times of post-harvest ploughing in their effects on profile water storage and subsequent crop performance in four two-year trials.
Four 2-year trials were set up to test the effect of crop sequences and periods of bare fallowing on the conservation of moisture in soil profiles in a harsh, semi-arid environment. Amounts of moisture remaining after the harvest of the first-year crop were in the order: bare fallow > cowpea > sorghum. Subsequent losses over the crop-free winter period were generally low, ranging 0.07-0.17 mm day^{-1}, according to the initial wetness of the profile and to the use or non-use of post-harvest tillage to control weeds and crop rationing. Significant effects of the previous crop on the performance of the second-year test crop were seen in all four trials, with average yields in the proportion: ex-fallow, 1.0; ex-cowpea, 0.81; ex-sorghum, 0.40. Although soil moisture content at planting time was a major factor in these differences, other factors could be important according to the nature of the season. For example, residual nitrogen from the preceding cowpea crop was beneficial when the test crop received good rainfall.
The above results suggest that bare fallowing is consistently effective in conserving soil moisture. In each of ten trials, a sorghum crop following a bare fallow outyielded one following a cereal (maize or sorghum). The long-term means were 1730 and 860 kg ha^{-1}, respectively. Simple arithmetic, however, shows that there was no appreciable difference in long-term productivity unit $area^{-1}$, on average, a bare fallow/sorghum rotation gave twice as much grain half as often. There is little in this to attract the small farmer, whose time horizon is necessarily short and who sees little point in ploughing and weeding land that carries no crop. For the larger, more mechanized farmer the greater reliability of yield conferred by bare fallowing might make the operation worthwhile.
Whole-season bare fallowing is clearly not the most efficient way of utilizing rainfall under Botswana conditions. In most years

there will be at least 250 mm rain falling in storms sufficiently heavy to penetrate the soil profile deeply enough for storage, but at most the soil can store only 100 mm available moisture. This discrepancy provides the rationale for part-season bare fallowing. The four trials reported here are too few to draw any firm conclusions, but it is significant that the yield following cowpeas was, on average, 81% of the following fallow, compared with just 40% for that following sorghum.
The results support the use of a short-cycle cowpea/sorghum sequence and where the present arable system is predominantly one in which sorghum or sorghum-dominated mixtures are planted every year on the same field, this is a significant finding.
The proposal of alternative farming systems for Botswana based on the soil as a moisture reservoir remains a valid concept.
One may consider physical structures to channel and store surface water, but for most farmers the main reservoir will remain the soil itself. To utilize this effectively, one needs a system involving short- and long-cycle crops, with periods of short-term, weed-free fallows in between.

993

91 - 11/40

Water management
USA, Kentucky, study, soil water conservation, tillage systems, fertilizer rates, cover crop management, maize, soil temperature, soil moisture

MUNAWAR, A.

Tillage and cover crop management for soil water conservation.

Agron. J., 82, 1990, pp. 773-777

The objective of this study was to determine the relationships between tillage systems, N fertilizer rates, and management of a rye cover crop on soil temperature, soil water, and corn yields.
Conventional tillage has been criticized for wasting energy and for contributing to soil erosion and related problems of air and water pollution.
Conservation tillage has been heralded as a way to save time, fuel, and labor and for increasing soil water supplying capacity to crops.
Along with the several advantages gained from conservation tillage are several effects that may be detrimental. The greater water retention may cause the soil to be too wet under certain soil and environmental conditions, especially in poorly drained soils. The population of denitrifying bacteria increases in the presence of a mulch. Consequently, loss of fertilizer N by denitrification is potentially greater and N management is more critical in conservation tillage than in conventional tillage. Lower soil temperature resulting from crop residues on the surface can be an important factor affecting emergence and seedling growth under conservation tillage in mid-latitudes, especially under no-tillage.
The effects of tillage systems, N fertilizer rates, and cover crop management on soil temperature, soil moisture, and corn (*Zea mays* L.) yields was determined in this work. Tillage treatments were chisel-plow tillage, conventional tillage (moldboard plowing and disking), disk tillage, and no-tillage.Nitrogen fertilizer at rates of 0,75, 150, or 225 kg N ha^{1} were broadcast on the soil surface. Rye (*Secale cereale* L.) on one-half of each split plot was killed 3 wk before corn planting time, while the other half was allowed to grow until the corn was planted. Corn yields in 1986 were 4.41, 4.03, 3.64, and 2.25 Mg ha^{-1} for no-tillage, chisel-plow tillage, disk tillage, and conventional tillage, respectively. The yields were significantly greater with early killed rye (3.85 and 5.05 Mg ha^{-1} in 1986 and 1987, respectively) than with late-killed rye (3.32 and 4.58 Mg ha^{-1} in 1986 and 1987, respectively). Soil temperature tended to be slightly higher under the late-killed rye mulch in 1986 with no significant difference in 1985. Soil moisture content was significantly higher for early killed rye treatment in the early part of the season in 1986 because there was less soil moisture depletion due to the growing rye.

Several practical implications can be drawn from this study. Corn yields in conservation tillage systems were equal to or better than in conventional tillage. Chemically killing a rye cover crop 2 to 3 wk before planting corn may conserve water for the corn crop without sacrificing the desirable benefits of a cover crop. This practice would be more important on potentially droughty soils. The early kill of the cover crop is a means of lowering the risk of water stress during the early growth of corn. Allowing a cover crop to grow up to corn planting time may adversely affect the subsequent corn crop by competing for soil water. During years of high spring rainfall, it may be advantageous to allow the cover crop to grow longer to dry out the soil and produce more dry matter for surface mulch, which will conserve water more efficiently for the corn crop during the summer.
These results are interesting and can contribute to soil and water conservation in developing countries as well, except for chemically killing cover crops. This practice cannot be recommended for reasons of long-term effects on the environment.

994

91 - 11/41

Water management
Asia, Malaysia, study, irrigation systems, costs and benefits, single factor analysis, multiple regression analysis

TAYLOR, D.C. and K. TANTIGATE

Costs and performance of irrigation systems of different sizes, types, and locations in Malaysia.

In: Irrigation Management: Research from Southeast Asia, Ed. T. Wickham, Thailand; Publ. by Agricultural Development Council, Inc. USA, 1981, pp. 49-63

This paper presents an analytical framework for formulating long-term irrigation policies for Malaysia and draws conclusions based on past and current experience.
This paper consists of four sections. The first describes existing irrigation systems in Malaysia with particular reference to size, type, and location. The second outlines the methodology of the study, and the third summarizes the results. Conclusions and policy implications are discussed in the last section.
Irrigation systems are located throughout Malaysia, but have greater geographic concentration in the Northwestern and Northeastern parts of Peninsular Malaysia. Essentially all of this irrigated area is used for the production of lowland rice.
Eighty percent of the systems irrigate less than 200 ha each; these smallest systems account for about 12 percent of the country's total irrigated area, but only 4 percent of total rice production. The 19 percent of systems ranging in size from 200 to 10,000 ha account for 37 percent of total irrigated area and about 23 percent of total rice production. The four largest systems, with over 10,000 ha each, account for slightly more than half the irrigated area and almost three fourths of the country's total rice production.
Irrigation in Malaysia is restricted almost entirely to run-of-the river diversion sources or pumped sources of river water.
The findings suggest that there may be economies to scale in constructing small and medium sized (less than 10,000 ha) diversion irrigation systems, but this relationship does not apply to pump and controlled drainage systems. The per ha cost of operating and maintaining larger systems also tends to be less than that of smaller ones except for those between 100 and 300 ha in size. Larger systems have higher annual yields and percent of land utilization than do smaller systems.
Among small and medium size systems, pump units are the highest cost systems, followed by diversion and controlled drainage systems. Diversion systems, however, seem to perform better than pump systems both in terms of annual yields and extent of land utilization.
Cost performance of irrigation vary considerably from one region to another.

From an economic standpoint, these findings suggest some caution in policies to encourage small scale irrigation, pump systems, and irrigation systems in certain regions of the country. More detailed studies of irrigation systems of different sizes and types, and in different locations, would provide more complete information for use in formulating irrigation policies. It is also recognized that decisions regarding the future development of Malaysian irrigation will ultimately be made on the basis of information integrating economic efficiency with many other objectives.
Suitability of a particular type or size of system in a given location is strongly conditioned by physical factors.

995 91 - 11/42

Water management
Study, tropics, water requirement, tomato, evapotranspiration models, soil water balance method, irrigation scheduling concepts, soil water measurements, alternative water management, greenhouse, rainshelter, protective tunnels, AVRDC

PHENE, C.J.

Water management of tomatoes in the tropics.

In: Tomato and Pepper Production in the Tropics, AVRDC Publication No. 89-317, Shanhua, Tainan, ISBN 92-9058-037-2, 1989, pp. 308-322

The objectives of this paper are to consider the water requirement of the tomato, describe basic irrigation scheduling concepts, discuss the various alternatives introduced, and propose a management method which integrates several of the concepts discussed.
Adverse climatic conditions and soil characteristics are primarily responsible for the low productivity of tomatoes. Excessive rainfall often restricts access to the field, impedes soil aeration, leaches nutrients from the root zone, enhances weed growth and diseases, and reduces the efficacy of fertilizers and pesticides. Constant high temperature and humidity conditions and the sensitivity of tomatoes to water stress and poor soil aeration also inhibit the development and growth of tomatoes.
In the tropics and other humid regions, the problems of normal irrigation management are aggravated by erratic rainfall which may exceed the soil storage capacity, causing nutrient losses from the root zone and deficient aeration.
The various methods discussed need to be integrated into a total water management system. Water management constraints and suggested systems and procedures for correcting or preventing the problems are summarized as follows:

- **Control waterlogging of soil bed:**
  . select coarse-textured soils
  . raise bed with organic matter (compost)
  . use organic mulching (rice straw)
  . install subsurface drainage system
  . level land to a given slope to promote surface drainage
- **Control growth of weeds:**
  . use organic mulching
  . maintain dry soil surface on bed
- **Control diseases within soil and above soil:**
  . install rainshelters
  . practice integrated pest management
- **Prevent leaching of fertilizers:**
  . use rainshelters
  . use slow release fertilizers
  . use organic fertilizers and compost

- **Control level of water table:**
  . grade soil surface to promote surface drainage
  . improve irrigation sheduling and use high-frequency irrigation
  . install controlled subsurface drainage system
- **Improve sunlight interception by canopy:**
  . space and orient beds for maximum sunlight interception
  . adopt plant population for incoming sunlight
- **Minimize plant water and nutrient stresses:**
  . irrigate with high-frequency subsurface drip system

Fumigation practices as proposed in this paper should be used only under extreme conditions and not as a routine method. The long-term environmental consequences should be considered.

996 91 - 11/43

Water management
Asia, Philippines, field trials, rice, sorghum, monocropping, grain yield, water use efficiency, IRRI

MORRIS, R.A. et al.

Water use by monocropped and intercropped cowpea and sorghum grown after rice.

Agron. J., 82, 1990, pp. 664-668

Recently developed rice cultivars mature in 100 to 115 d, about 60 d earlier than most traditional tropical rices and 25 d earlier than most first-generation modern rice cultivars. These new rice cultivars have created opportunities to grow crops on residual soil water and occasional dry season rains.
During the dry season, rainfed crops must rely on residual soil water as a major source for transpiration because rains are irregular. Information is needed to develop new cropping system management schemes to use residual water efficiently.
Water used by monocropped and intercropped cowpea (*Vigna unguiculata* (L.) Walp) and sorghum (*Sorghum bicolor* (L.) Moench) treatments grown on a fine, mixed, nonacid isohyperthermic Andaqueptic Haplaquoll after harvesting flooded rice was compared to water lost from a fallow treatment. Determinations were to 1.1 m. Water used before cowpea harvest was similar within a treatment among years, but among treatments monocropped cowpea used 172 mm, monocropped sorghum 135 mm, the intercrop 162 mm, and fallow 121 mm. Water used between cowpea and sorghum harvests ranged from 22 to 118 mm, varying with rainfall after cowpea harvest. Species were compared by expressing grain yields in mg glucose hectare^{-1} required to synthesize grain. Glucose equivalent yields from monocropped cowpea ranged from 1.90 to 1.98 mg glucose ha^{-1}, monocropped sorghum from 1.99 to 3.66 mg glucose ha^{-1}, and the intercrop from 1.99 to 4.36 mg glucose ha^{-1}. Mean water use efficiency by monocropped cowpea, monocropped sorghum, and the intercrop was 11.3, 12.4, and 16.5 kg glucose ha^{-1} mm^{-1}. Monocropped cowpea and the cowpea-sorghum intercrop each use about 50% more water than is lost from fallow.
Concluding, the three crops (monocropped cowpea, monocropped sorghum, and the cowpea-sorghum intercrop) used water remaining in the soil profile which otherwise would have been lost by evaporation and drainage. Monocropped cowpea used more water than monocropped sorghum did during the cowpea growing period. Monocropped cowpea and the intercrop, however, used similar quantities during the same period. Water use by monocropped and intercropped sorghum during the post-cowpea period varied with rainfall during that period. Cowpea yields were more stable than sorghum yields, probably because cowpea growth was less dependent on rainfall. Although the quantities of water used by monocropped cowpea and the cowpea-sorghum intercrop were similar, the intercrop used the water more efficiently.

Intercropped species that compete for the same limiting factor but at partially different times or from partially different zones use the factor more efficiently than it is used by a monocrop of either component species.
If the agronomic objective of dry season cultivation is to use residual soil water remaining after rice harvest to produce a crop with low annual yield variation, monocropped cowpea is superior to monocropped sorghum or a cowpea-sorghum intercrop. If the objective, however, is to maximize the efficiency of residual soil water as well as that from occasional late dry season rains, a cowpea-sorghum intercrop will be superior although yields will probably be less stable than those of monocropped cowpea.

XII SOIL FERTILITY

997 91 - 12/50

Soil fertility
Review, book, soil conservation, smallholder, humid tropics, land degradation, shifting cultivation, population increase, food supplies, permanent farming, upland farming, employment, institutional practices, cultural conditions, socio-economic environment, policy implications, FAO

SHENG, T.C.

Soil conservation for small farmers in the humid tropics.

FAO Soils Bulletin, 60, ISBN 92-5-102869-9, 1989, 104 p., FAO Publications Division, Via Delle Terme di Caracalla, 00100 Rome, Italy

This bulletin describes problems, approaches and techniques of soil conservation in the humid tropics and in particular is intended to assist farmers to overcome their soil erosion problems.
In the humid tropics soils tend to contain most of their fertility in the top few centimetres of their profile. If these soils are exposed, and left unprotected from the frequent, high-intensity rainstorms which are common, they can quickly erode, losing their fertile topsoil and leaving behind poor, infertile land.
A better appreciation of the value of soil conservation is obtained by recognizing two categories of benefit; on-site benefits and off-site benefits.
In developing countries, soil conservation programmes can generate other major benefits which are often overlooked. These other benefits are outlined:

- Inducing permanent farming:
  Given proper soil conservation and management, many areas could be farmed permanently and much more intensively without risking undue erosion. For example, the construction of bench terraces would permit settled, continuous farming in many areas where shifting cultivation is presently being practised.
- Increasing the population supporting capacity of the land:
  Well-planted soil conservation introduces a better choice of land-use, improved farming practices, conservation of soil moisture and other measures designed to increase agricultural production and thus raise the population supporting capacity of the land. In some countries, cultivated land can support only 2.5 to 5 people per hectare while in some Asian countries up to 15 people on each hectare of their terraced paddy lands are supported.
- Developing new land safely:
  FAO has estimated that to feed the world in the year 2000 an additional 150 to 200 million ha of new land should be brought into production. This expansion will inevitably embrace land

  inherently less favourable for farming, such as more steeply sloping land in the humid tropics. Sound soil conservation measures will be essential to the safe development of these kinds of land on a sustained basis.
- Modernizing upland farming:
  Upland farming in many countries remains primitive because the hilly terrain is rough and remote. Properly designed conservation structures in these areas will not only protect the hillslopes but will also provide better access, better drainage and increased potential for mechanization and irrigation.
- Providing employment opportunities:
  Soil conservation and land use intensification activities could create much-needed employment opportunities in the rural areas of many developing countries. Most traditional soil conservation practices are highly labour-intensive.

FAO has produced this Soils Bulletin as a reference for the planners and technicians working with small farmers in the humid tropics.