Further studies would be required to determine if such increases are due only to better weed control or also to better nutrient uptake or water conservation.
Considering only land-equivalent ratio (LER), there was a yield advantage in intercropping, and up to 55% and 104% more land would be required under sole crops to produce the yields achieved in mixtures in the early and late planting seasons, respectively.
Based on these results, 20,000 plants of groundnut, cowpea or melon ha^{-1} can be used as smother crop in cassava + maize mixture to give good weed control and high mixture yield.

1222 92 - 10/149

Plant protection
Africa, Ethiopia, weed control, intercropping, bean

ABATE, T.

INTERCROPPING AND WEEDING: EFFECTS ON SOME NATURAL ENEMIES OF AFRICAN BOLLWORM, *HELIOTHIS ARMIGERA* (HBN.) (LEP., NOCTUIDAE), IN BEAN FIELDS.

J. Appl. Ent., 112, 1991, pp. 38-42

Intercropping is an age-old practice that has been used by subsistence farmers in the tropics to suppress pests and to increase crop yield. One advantage of diverse environments, such as intercropped and weedy fields, is that they result in greater natural enemy numbers because they provide shelter and alternative food sources for natural enemies. In general, natural enemy numbers are known to be greater in diverse environments than in monocultures.
The objective of the experiment discussed here was to determine the effects of intercropping and weeding on pests and natural enemies.
The effects of strip-cropping haricot bean (*Phaseolus vulgaris* L.) with maize (*Zea mays* L.) under weedy and weed-free conditions on the abundance of tachinid parasitoids and a predatory wasp that are associated with African bollworm were studied at Awassa, southern Ethiopia, during the 1987 and 1988 crop seasons.
Results of the experiments described above demonstrated that tachinid parasitoids and *Tiphia* sp. were more abundant in diverse bean plots than in bean monoculture. This may give one possible explanation for the low level of *Heliothis armigera* numbers and hence less pod damagae in haricot bean strip-cropped with maize in previous experiments. Increases in natural enemy numbers in diverse environments are consistent with reviews and reports by several authors. It is possible that the availability of other food sources, such as pollen and nectar, are responsible for increased numbers of natural enemies in diverse environments.
Increase in natural enemy numbers, and consequently decreases in pest numbers, brought about by the presence of weeds are not usually adequate, at least in the short-run, to offset yield losses caused by weeds, especially when more than one pest species are important in a particular crop. If properly managed, intercropping and weed management have a great long term benefit in the integrated management of *Heliothis armigera* and other pests in bean fields.

XI WATER MANAGEMENT

1223 92 - 11/44

Water management
Review, water conservation, irrigation management, drainage, reclamation, environmental management, water supply

CARR, M.K.V. et al.

WATER MANAGEMENT.

Outlook on Agriculture, 19, 4, 1990, pp. 229-235

In this paper, water management issues in the rural sector are considered under five main headings: making the best use of rainfall or water conservation, irrigation water management, drainage and land reclamation, environmental water management, and rural water supplies. Each of these topics is considered in turn, using examples from research and consultancy projects to illustrate some of the issues of current international concern.
Traditional engineering disciplines recognize that water must be managed in sustainable and environmentally friendly ways. This requires bridge building between specialist subject areas including ecology as well as agronomy, soil science as well as soil mechanics, hydrology as well as hydraulics, and sociology as well as economics. These values have implications in terms of research priorities and educational needs, as well as for the policies of governments and international agencies.
The unreality of imposing engineering solutions on water management problems without taking into account the social consequences of such action, the ease of operation and maintenance and the expected environmental impact are recognized. A favourable cost-benefit analysis on its own is no longer enough to convince a funding agency, the client or the general public that the solution proposed is the correct one. Sustainability has become the new watchword.
For the vast majority of the world's farmers, irrigation is not an option: they depend on rainfall for successful crop and animal production, and for survival. In areas of the world where rainfall is marginal or unreliable, the priority is to optimize the use of the rain through the use of appropriate, usually low cost, crop husbandry techniques.
Concluding, each of the topics discussed is of international concern: water does not recognize national boundaries, and neither does the pollution with which it may be associated. The relative importance of different issues varies from place to place and from country to country. What can be afforded also varies, but appropriate solutions can be found, providing the complexity of the systems is recognized, as well as the self-interest of human beings.

1224 92 - 11/45

Water management
Review, article, developing countries, irrigated agriculture, crop diversification, water management constraints, crop water requirements, irrigation systems, soils, irrigation canals, cultivation methods, water delivery, World Bank

PLUSQUELLEC, H.

CROP DIVERSIFICATION IN IRRIGATED AGRICULTURE: WATER MANAGEMENT CONSTRAINTS.

In: Proc. of the Seventh Agric. Sector Symposium Sustainability Issues in Agricultural Development; World Bank, Washington, D.C., USA, ISBN 0-8213-0909-0, 1987, pp. 313-319

This paper reviews first the different water requirements of paddy and upland crops and reviews the general technical features of the two dominant surface irrigation methods, basin and furrow irrigation used in developing countries. Then the paper discusses the issue of improving irrigation facilities to make possible the shift from paddy cultivation to other crops and/or the adoption of mixed cropping. This review is limited to the aspects relevant to crop diversification and does not pretend to fully cover the above subjects.
Besides marketing considerations, diversification from rice paddy to non-paddy crops in irrigated agriculture is constrained by several physical and institutional factors such as soils, farmers' experience, credit, extension services and irrigation facilities.
The issue of crop diversification is limited to surface irrigation which is the predominant method used for more than 90 percent of the 275 million ha currently irrigated in the world. In the vast areas of lands irrigated in Asia, surface irrigation methods are used almost exclusively for both paddy and upland crops.
The precise water control needed for diversified field crops requires in general extension of the tertiary networks, improvement and modernization of the main and distribution system, and in some areas, improvement of the drainage and flood control conditions.
The issue of improvement/modernization of irrigation systems to permit crop diversification has been complicated by the sharp drop in projection rice prices that occurred since 1982.
The 1990 rice price projections dropped from about 600 US$ in 1982 to 339 US$ in 1984/85 and recently below 250 US$. Most of the rice irrigation projects were viable in the early 80s including those for which all the infrastructure from storage or diversion works down to the on-farm water delivery works had to be built. Under the 1984/85 economic conditions, the viable investments in rice projects were those taking advantage of sunk costs in existing infrastructure.
In the case of Thailand a fast method for screening viability of projects was developed for the Irrigation Subsector Review issued in April 1986. It was found that development of the tertiary

system at a low cost of US$ 600/ha is viable with only a modest paddy yield increase of 0.5 ton/ha in each season assuming a cropping intensity of 150%. To justify the investment required for an intensive tertiary system including land levelling (US$ 1000/ha) a yield increase of at least 0.8 to/ha for each season should be achieved.
With the most recent price projections, a detailed analysis of each project would be needed because of the sensitivity of the rate of return at these low rice prices. Investments required to improve the tertiary system together with improvement of the distribution system may no longer be justified unless there is a substantial increase in yields (above 1 ton per ha) and/or an increase in cropping intensity by making use of the water saved through more efficient operation. The conclusion is that in a number of cases the improvement of irrigation systems at both the tertiary and distribution level may not be economically justified for increasing rice production alone, without diversification to higher value crops. The investments required for crop diversification would have to be undertaken only when there is sufficient indication that all the other preconditions for crop diversification are met: market, marketing facilities, extension services, etc. The same conclusion may be valid for other rice surplus countries.

1225 92 - 11/46

Water management
Review, watershed management, stream corridor system, water resource quality, land-use impacts, costs and benefits, USAID, DESFIL

DICKINSON, J. and F. TRACY

STREAM CORRIDORS IN WATERSHED MANAGEMENT

Publication of DESFIL; prepared for USAID under contract number 527-0000-C-00-7841-00; Development Strategies for Fragile Lands, 7250 Woodmont Avenue, Suite 200, Bethesda, Maryland 20814; 1989, 15 p.

Increasing human pressure on the land has accelerated soil erosion, reduced production and income levels, and created scarcities of wood and loss of natural systems. In practice, watershed management has focused on reforestation of degraded areas, on-farm soil conservation, and "works of art".
Interventions are rarely based on an integrated management plan addressing whether or where they are needed, if they are cost effective, or how they fit into an integrated management plan. Failure to distinguish in the field between relatively uncontrollable natural erosion processes and those that are accelerated by human activities can be costly and threatens the credibility of management approaches.
This paper specifically addresses the management of stream corridors. Sediments from uplands, together with materials excavated by streams themselves, move through a network of stream corridors. How these corridors are managed is critical to the achievement of both local and downstream benefits from overall watershed management activities.
Stream corridors form the transitional zone of significant interaction between a terrestrial and an aquatic ecosystem.
Stream corridor management includes the maintenance of riparian and instream vegetation and maintenance of overall channel morphology with its obstructions, rapids, meanders and adjacent wetlands. These actions together result in:
- Filtering of sediments contained in overland runoff;
- Reduction in bank erosion;
- Attenuation of flood peaks;
- Control of eutrophication in headwater streams;
- More productive fisheries; and
- Maintenance of the diversity of stream corridor ecosystems.
Stream corridor management is most effective in delivering these benefits if integrated into an overall program of watershed management. Effective management of headwater streams offers higher benefits per stream segment affected. If headwater stream corridors are neglected, management of river segments in the lower reaches of a watershed will be less effective.
Financial resources are never sufficient to permit all possible management interventions in watersheds thousands of hectares in

extent. Scarce resources must be allocated to those activities which together contribute most to overall system maintenance, the well-being of local populations, and to downstream water resource users. Stream corridor management, particularly along smaller streams in both upper watersheds and lowlands, can be a cost-effective contribution to a watershed management program.
An integrated two-step ecological engineering approach to stream corridor management is recommended. First is the establishment or preservation of the filtering capacity of the corridor vegetation that serves as the buffer between the stream itself and the rest of the watershed. Second is the maintenance of the biological and physical integrity of the stream ecosystem itself. This involves protecting the stream from such direct impacts as channelization, waste dumping, and livestock watering. If both steps are effective in maintaining the integrity of the corridor with its riparian and aquatic components, then the maximum range of goods and services of local or downstream value (fisheries and wildlife, recreation, water for domestic, agricultural and industrial use, and waste removal and treatment) can be provided. Smaller streams, because they compose a major proportion of the length of channels in a watershed, serve as the major area of interface between stream corridors and the surrounding watersheds.
The purpose of this paper was to demonstrate how stream corridor management plays an integral role in the management of watersheds for sustainable development. Stream corridors are among the most fragile elements of upper watersheds, both in mountainous areas and in the upper reaches of streams in the wet tropical lowlands. In addition to the multiple values represented by stream corridors, these areas are a magnet to conflicting uses. How human needs for food can be met while maintaining other values both on site and downstream has been our concern. Among the use strategies advocated for fragile lands has been the modification of existing small farm production activities by introducing tree-based agroforestry and silvopastoral systems to produce food and raw materials from combinations of annual and perennial cropping and livestock. These uses are complementary to, and may even be included among, the uses advocated for stream corridors.

1226 92 - 11/47

Water management
Review, Mexico, India, Iran, Pakistan, Australia, water harvesting systems, case examples, catchment areas, water storage, water harvesting constraints, water harvesting strategies, water quality, sources of water, precipitation, knowledge gaps, FAO

THAMES, J.L.

WATER HARVESTING.

In: Proc. of the FAO Expert Consultations on the Role of Forestry in Combating Desertification, Saltillo, Mexico, 1985; FAO Conservation Guide No. 21, 1989; ISBN92-5-102802-8

The earliest evidence of the use of water harvesting are the well publicized systems used by the people of the Negev Desert perhaps 4000 years ago. Hillsides were cleared of vegetation and smoothed in order to provide as much run off as possible; the water was then channeled in contour ditches to agricultural fields and/or to cisterns. By the time the Roman Empire extended into the region, this method of farming encompassed more than 250,000 hectares.
Water harvesting is a technique of developing surface water resources that can be used in dry regions to provide water for livestock, for domestic use, and for agroforestry and small scale subsistence farming.
Water harvesting systems may be defined as methods whereby precipitation can be collected and stored until it is beneficially used. The system includes a catchment area, usually prepared in some manner to improve run off efficiency and a storage facility for the harvested water, unless the water is to be immediately concentrated in the soil profile of a smaller area for growing drought-hardy plants. A water distribution scheme is also required for the systems devoted to subsistence farming for irrigation during dry periods.
A successful system must be:
- Technically sound, properly designed and maintained.
- Economically feasible for the resources of the user.
- Capable of being integrated into the social traditions and abilities of the users.

Water harvesting offers methods of effectively developing the scarce water resources of arid regions. As contrasted to the development of groundwater, which is usually a finite water resource in arid zone, the method allows use of the renewable rainfall which occurs, even though in limited amounts. It is also a relatively inexpensive method of water supply that can be adapted to the resources and needs of the rural poor. It is necessarily small scale, and as such it can provide stability and improve the quality of life in small rural communities and that of small land holders who are several stages removed from the benefits of large scale development projects. It involves some risk, dependent upon the vagaries of climate. New skills, though

simple, are required, maintenance is a constant necessity, and good design is imperative.
There is no universally "best" system of water harvesting. However, there will be some type of system that can be designed to best fit within the constraints of a given location. Each site has unique characteristics that will influence the design of the most optimum system. All factors, technical, social, physical and economic must be considered.
During the past two decades, there have been many water harvesting systems constructed and evaluated at a number of different places in the world. Some of the systems have been outstanding successes, while others were complete failures. Some of the systems failed, despite extensive effort, because of poor design or the materials used. Other systems failed despite good design and proper materials because social factors were not integrated into the systems. These systems failed because of poor communication and lack of commitment by the local people both in planning and financing the projects.
Sufficient knowledge and experience has been accumulated to put into operation water harvesting projects throughout the arid lands of the world. Empirical information and documentation is needed from successes as well as failures on which to build a more exact technology.

1227 92 - 11/48

Water management
Case study, USA, irrigation systems, costs and benefits, cotton production

LETEY, J. et al.

AN ECONOMIC ANALYSIS OF IRRIGATION SYSTEMS.

Irrigation Science, 11, 1990, pp. 37-43

The objective of this paper is to determine the economically optimal irrigation system for a set of conditions which are specified.
Irrigation systems are evaluated based on their performance and costs in relation to cotton production and drainage volumes. The latter factor is becoming increasingly important in some irrigated lands such as in the San Joaquin Valley of California where appropriate disposal of subsurface drainage water may become very expensive because of the total dissolved solids and presence of toxic elements in the drainage water. Cotton was selected as the crop for analysis because it is a major crop on irrigated lands and it is amenable to irrigation by several systems. Furthermore, it is a principal crop grown in the western San Joaquin Valley of California which will serve as a case study for the report.
An array of irrigation systems are available which can be broadly classified as being gravity flow or pressurized. Pressurized irrigation systems provide better control on the amount of applied water and, in most cases, better irrigation uniformity than gravity flow systems. They also have a higher initial capital cost than gravity flow systems and an analysis is required to determine whether the improved performance of pressurized systems justifies the additional costs. An economic analysis was done on several irrigation systems which included consideration of farm management costs associated with a given irrigation system, shifts in crop yield and drainage volumes associated with the optimal management of each irrigation system, and costs associated with disposal of drainage waters. Irrigation uniformity is a significant determinant to the results. Although irrigation uniformities can be highly variable based on design, maintenance and management, a typical uniformity for each irrigation system was selected. For the conditions of the analysis, gravity flow systems were calculated to be more profitable than pressurized systems if there was no constraint on the amount of drainage water generated or cost for its disposal. Imposition of costs for drainage water disposal induced a shift whereby pressurized systems became more profitable than gravity flow systems.
Irrigation systems can be broadly classified as being either gravity flow or pressurized.
Because of the limited number of irrigations, a furrow system might be very difficult to manage in a manner to obtain the desired drainage volume without missing the mark considerably resulting in either higher or lower drainage volumes and profits.

One advantage of the pressurized irrigation systems is that they can be managed to obtain maximum yields and yet produce low drainage volumes.
In conclusion, the economic advantages of a given irrigation system depend on an array of factors. Variations in farm management costs associated with a given irrigation system must be considered in addition to initial capital investment costs. Furthermore, shifts in yield and drainage volumes under optimal management for different irrigation systems can provide additional costs or benefits associated with a given irrigation system. Imposition of costs on drainage water could induce a significant shift in profitability associated with a given irrigation system.

1228

92 - 11/49

Water management
USA, Mexico, arid regions, semiarid regions, field trials, crop production, microcatchments, desert-strip-farming systems, rainfed production

FLUG, M.

PRODUCTION OF ANNUAL CROPS ON MICROCATCHMENTS.

In: Rainfall Collection for Agriculture in Arid and Semiarid Regions; Publ. of CAB, UK; ISBN 0-85198-486-X, 1981, pp. 39-42

Water harvesting for agriculture is an ancient art with proven usefulness for producing food in arid and semiarid regions of the world.
Water is often the limiting natural resource in these regions. The greatest potential for augmenting available water supplies rests in the collection and conservation of precipitation. An estimated 95% of precipitation in arid and semiarid regions of the world is lost to evaporation. A small reduction in these evaporation losses would substantially increase the quantity of water available to agricultural, industrial, and municipal concerns. Agriculture is by far the largest consumer of water, and therefore, conservation in agriculture or substitution of harvested water for traditional water sources in crop production would release large quantities of water to other sectors of society.
Although natural precipitation in an area may be inadequate to raise a crop, enough water can be collected from an entire region for ample crop yields on a portion of the region. Water harvesting enables a greater percentage of precipitation to be put to beneficial use in a water efficient agricultural system.
Some of the simplest water-harvesting systems collect 20% to 40% of the precipitation for later beneficial uses, while a more elaborate system can collect more than 90%.
A number of water-harvesting systems have been developed to suit given regions, crops, and rainfall patterns. Desert-strip-farming experiments to grow two crops per year began in 1978 at the University of Arizona Page Trowbridge Experiment Farm (Page Ranch). Desert-strip-farming is similar to conservation bench-terrace farming and conventional dryland-strip farming in which crops are planted along contours. An important difference, however, is that the fallow areas are used as catchments. The catchment area is often cleared of vegetation shaped, smoothed, compacted, and even treated with sealants to increase runoff efficiency. Furthermore, the adjacent cultivated area, which is formed by leveling a swath along the contour, has a small dike on the downhill side to trap runoff water. Another difference is that unlike dryland-strip farming, where the ratio of fallow to crop is usually 1:1, desert-strip-farming is based on % ratio that varies with the environmental conditions of each specific site. Other variations among systems derive from different methods of treating catchments and storing water.

An important concept in understanding water-harvesting systems is the ratio of catchment area to cultivated area (CCAR). The CCAR depends upon the runoff efficiency of the catchment area, the crop moisture requirements, and the expected quantity and temporal distribution of precipitation. Moisture requirements are determined from consumptive use data for the particular crop and are adjusted to the date of planting and associated considerations.

1229

92 - 11/50

Water management
Africa, developing countries, Transkei, Ciskei, irrigation projects, case studies, management, human factors, agricultural production, institutional constraints, socio-economy, culture, tradition, inputs, research needs

BEMBRIDGE, T.J.

PROBLEMS AND LESSONS FROM IRRIGATION PROJECTS IN LESS DEVELOPED COUNTRIES OF AFRICA.

Development Southern Africa, 3, 4, 1986, 19 pp.

This paper reviews important constraints to the development of small-holder irrigation schemes in less developed areas of Africa. It is based on two case studies from Southern Africa and experience elsewhere on the continent. Lessons from past experience and the institutional and human development considerations required for successful projects are discussed.
A survey of the literature on Third World irrigation projects, and in Africa in particular, shows that with few exceptions the economic success of irrigation projects falls far short of the expectations of planners, politicians and development agencies. Even on the few relatively successful projects, there appear to be increasing social and ecological problems which will eventually have negative economic effects.
At present, irrigation plays a rather insignificant role in African agriculture. Of Africa's 150 million hectares of cultivated land, only about 9 million hectares are under irrigation. Of this, approximately 75 per cent is in Egypt, the Sudan and Madagascar. Small-holder irrigation in Africa is generally characterized by low productivity. Persistently low performance on irrigation projects poses one of the biggest problems for planners, policy makers, financing agencies, managers and participants alike. As African nations face a continuing decline in per capita food production, increasing priority is being given to irrigation development. National development plans of countries such as Kenya and Zimbabwe, as well as some of the independent South African states, such as Ciskei, Transkei and Venda, emphasize the role of small-holder irrigation development for food as well as rural development.
By its very nature, irrigation development is particularly prone to human problems. This is because the introduction of irrigation commonly necessitates a change in the way of life of those participating in irrigation projects, making it difficult for planners to predict future human behavior.
This review, faced as it was by space considerations, has been somewhat too generalized to make sweeping conclusions. However, considering available literature and the two case studies reviewed in this paper, it can be concluded that success depends on integration between technology, management, participants and the socioeconomic situation. Poorly planned projects suffer from lack

of such integration, especially in the field of management, organization and implementation. The institutional environment in which irrigation takes place has received little attention from irrigation planners. Infrastructural development and economic constraints are rarely so bad as to cause collapse of the project. The causes of the lack of success of individual irrigation projects in Africa are complex. One of the problems is the one-sided emphasis on the technical components of projects. At the basis of this is the attitude of many project planners and managers who primarily measure the success of projects according to physical development and agricultural production. Such a viewpoint neglects the fact that projects have not only a technical but also an equally significant socioeconomic character. In view of this, it makes sense to regard development projects as socio-technical systems which can only be deemed to be successful when all persons and groups concerned co-operate effectively and satisfy their objectives. This co-operation will vary according to the type of project.

On the basis of this review and experience in Africa, certain prerequisites for successful small-holder irrigation development have been defined:

- Institutional requirements
- Human development

The importance of engineering, agronomy and soils' research are not being minimized; nevertheless this paper has shown that in less developed countries institutional, social and economic aspects are generally responsible for poor performance and therefore require more research.

Retrospective studies of management and performance could be integrated into any technical or socioeconomic rehabilitation which may be required.

In the long run, there is a need for integration of evaluation research at successive stages of a project. It is vital that mechanisms be developed for proper assessment and evaluation to modify projects when necessary, as well as avoid unnecessary expenditure on projects which are doomed to failure.

1230

92 - 11/51

Water management
Asia, Pakistan, study, sample villages, irrigation organization, irrigation management, water supply, water resources, water distribution system, water allocation, maintenance operations

MIR KALAN SHAH

IRRIGATION ORGANIZATION AND MANAGEMENT.

In: Stability and Changes in Rural Institutions in North Pakistan; Ed. W. Manig; Alano Edition Herodet, F.R.G., 1991, pp. 141-153

The present study is an effort to investigate the nature of water distribution and its management in the six selected villages in Peshawar District.

Water is one of the basic components of modern agricultural input used in Pakistan. Therefore, the development of irrigation and improvement of irrigation systems both at the micro and macro level are crucial for Pakistan's agricultural development. The availability of additional water helps in extending the area under cultivation and enhances the cropping pattern from low to high value crops. Improved management can probably do more towards increasing agricultural production both of food and other crops in the irrigated areas of the world than any other agricultural practice. In an agrarian economy, irrigation may be a good source of employment. It raises both the employment and income of the land and adds to capital formation.

For the investigation a questionnaire was prepared. The survey of all of these villages was carried out in order to have some basic information. Purposive sampling methods were used for the selection of 110 farmers.

On the other hand, discussions were held with the officials from the irrigation department and their ideas were included to substantiate the study.

The irrigation system in Pakistan has undergone a remarkable change in present times. The old, customary field practices have been replaced by modern technology to ensure proper management of water. Efficient water management should be an essential feature of the irrigation planning. Integrated development of water resources, an efficient method of conveyance and distribution of water on the farm, a judicious method of water application, and a cropping pattern for high water-use efficiency, a specific time for irrigation, and removal of excess water are important aspects of a comprehensive irrigation development programme. Efficient water management largely depends upon selecting the methods best suited to local conditions because irrigation management systems differ from region to region in a country.

Concluding, water is one of the primary inputs for crop production. Proper timing and a judicious amount of use of this input along with scientific methods of application are important for achieving a good yield when properly combined with other inputs. One aspect of the poor performance of irrigation schemes

has been defective methods of water distribution between the farmers at the head and the tail ends of the water courses and inefficient management of the irrigation department. The current system has a history and tradition. The water rights were built up over the years. They cannot be easily changed, even by providing the equity element. No change in the system of water distribution has been reported by any farmer in the project area. The system of *warbandi* (water by turn) has prevailed for a very long time.
It was very clear that the farmers were in favour of water-users'organizations, but they have not been motivated for this purpose. It will require government incentives, assistance, and education and extension services in order to initiate such organizations. Additionally, the land-tenure system will also play an important role in such organizations.
The government of Pakistan is aware of the need for organizing the farmers at the "grass roots" level. The major problem at present is that the farmers have not been given the necessary information on a large scale, or incentives to improve their own farm irrigation systems. The time has come for a national emphasis or programme to involve the farmers in the improvement of their system and the optimal utilization of irrigation water. But it is important for the farmers to be allowed to work out their own organizational procedures which fit their particular situation. No attempt should be made to pressurize them to adopt a particular scheme that is foreign to their understanding. Thus, improvement and development must be carried out by and for the farmers themselves.

1231 92 - 11/52

Water management
Africa, Niger, Sudano-Sahelian Zone, soil water balance, state of the art, soils, soil water monitoring, ICRISAT

SIVIKUMAR, M.V.K. et al.

BILAN HYDRIQUE EN ZONE SOUDANO-SAHELIENNE: COMPTES RENDUS D'UN ATELIER INTERNATIONAL. (SOIL WATER BALANCE IN THE SUDANO-SAHELIAN ZONE: SUMMARY PROCEEDINGS OF AN INTERNATIONAL WORKSHOP).

Proc. of an Internat. Workshop, Niamey, Niger; ICRISAT, Patancheru, A.P. 502 324, 1991, 42 pp. LDC: 6.68 USD, HDC: 15.48 USD

This workshop aimed at evolving an effective synthesis of the state of water balance research in the Sudano-Sahelian Zone. It brought together scientists from different disciplines to share their experiences and to contribute to discussions.
Participants at the workshop discussed the issues concerning soil water balance in five technical sessions: Current Research and Future Implications; State of the Art of Soil Water Balance Research; Soils of the Sudano-Sahelian Zone; Soil Water Balance Studies in the Sudano-Sahelian Zone; and Operational Applications of Soil Water Balance Monitoring and Prediction.
This volume presents summaries of the five sessions, reports of the planning groups that dealt with the main issues for future research and collaboration - new systems and sites, measurements and analysis of weather, crop, and soil data, modeling, technology transfer, and management - and 21 recommendations for action covering future studies on water balance, definition of minimum data sets, collection and dissemination of information modeling, and training.

1232 92 - 11/53

Water management
Review, book, dryland, water conservation, soil conservation, erosion, wells, water lifting, surface water storage, organization for action

CHLEQ, J.L. and DUPRIEZ, H.

VANISHING LAND AND WATER.

Macmillan Publishers/Terres et Vie, 1988, 117 pp., ISBN 0-333-44597-X; distributor: CTA, P.O.B. 380, 6700 AJ Wageningen, Netherlands

Rains are infrequent in the semiarid regions such as the Sahel and Sudan savanna zones, which stretch across Africa from the west coast to the horn of Africa in the east and which include the Kalahari and Namib areas of southern Africa. The rains last 3-4 months of the year and are often erratic and torrential. Man is powerless to alter the rate of precipitation. On the other hand, he is not powerless when it comes to holding back, storing and using sparingly the rainwater that falls on his fields. Using methods to trap water and stop the loss of soil around the village, he can ensure water penetration for the benefit of crops, store water for periods of drought, and make sure that fertile clay stays in the settlement.
This book sets out to show how artisan crafts dealing with water supply problems can play an important role in village life in dry lands. Water crafts are direct and indirect sources of revenue. They are a direct source of income for water craft artisans and an indirect source of income for cultivators and pastoralists who benefit from the water resources on their land, thanks to the advice and skills of local artisans.
This book was inspired by village schemes in Sahelian Burkina Faso. They extended over a long period and involved close collaboration between villagers, artisans and technicians. These people worked together to find solutions to the problems of water runoff, and the use and exploitation of water resources. The techniques described are limited. Many other techniques exist and have been described in other publications. But what is striking about the experience of the GARY (Groupement des Artisans Ruraux du Yatenga = Group of Yatenga Rural Artisans) is that the level of practical skills acquired by villagers is quite high.
This book advocates cooperation between all the people concerned. The technical aspects, sometimes described in great detail, are only meaningful if they are accepted as something to be thought about by water technicians and their village partners. In other words, this book is not designed just for technicians. Its whole aim is to spark off useful discussions between the parties concerned. If this exchange is initiated, technical solutions will be found - maybe the solutions put forward here, or maybe others inspired by these solutions.

The Land and Life Series is aimed at practitioners and students of agriculture and rural development and associated vocational and technical skills. The books in the series treat topics according to appropriate, small-scale and affordable technology taking into account traditional ways but adding relevant modern improvements. For training, they can be used in secondary schools and vocational training centres and colleges up to the diploma and degree level, but they are chiefly meant to be used in the field, in practice. They are ideal for self-help, adult education and rural extension projects. They are written in a clear and highly illustrated style and thus can be used equally by those for whom English is a second language and by non-specialists. All the titles in the series are designed and produced as low-cost editions. Although based on African practice, the books are relevant to similar climatic regions in other continents.
The Land and Life Series is co-published with Terres et Vie, from whom French language editions are also available. Translation from French to English was financed by CTA.

1233 92 - 11/54

Water management
USA, field studies, water use, legumes, soil water, cropping systems

BADARUDDIN, M. and D.W. MEYER

WATER USE BY LEGUMES AND ITS EFFECT ON SOIL WATER STATUS.

Crop Science, 29, (5), 1989, pp. 1212-1216

To make informed decisions on whether to include legumes in cropping systems, information is needed on water use by legumes and its effect on soil water availability to subsequent crops. The objectives of this study were to determine the water use, water use efficiency (WUE), and soil water depletion pattern of four grain legumes and three green-manure or forage legumes. Field studies were conducted on a Fargo silty clay (fine, montmorillonitic, frigid Vertic Haplaquoll) at Fargo and on a Perella-Bearden silty clay loam (fine-silty, mixed, frigid Typic Haplaquoll; fine-silty, frigid Aeric Calciaquoll) at Prosper, ND in 1986 and 1987. Soil water to a depth of 2.2 m was determined by the neutron attenuation method at 15-d intervals. Legume crops used 10 to 25% more seasonal water than wheat (*Triticum aestivum* L.) across environments, but WUE (kg dry matter ha^{-1} mm^{-1} of water) of legumes was 0 to 25% greater than that of wheat. Green manure and forage legumes generally had greater water use and WUE than grain legumes, and this was associated with their longer growing season and higher dry matter production. Cumulative water depletion during June to September by green-manure, forage, and grain legumes was 70, 63, and 43 mm greater, respectively, than that of a fallow check, and was not significantly different from that of wheat in two of four environments. However, an increase in soil water content occurred at the 0- to 0.3- m soil depth for all treatments in the following spring across three environments. Soil water content in the spring following a legume was not significantly different from that following wheat and was only about 30 mm greater than that of fallow across environments. These results indicate that growing some legumes in cropping systems may not substantially affect the soil water content compared to continuous cereal cropping or to fallow.

1234 92 - 11/55

Water management
Asia, India, Himalayas, irrigation project, environmental impact assessment, sustainable development, water demand

AHMAD, A. and P.P.SINGH

ENVIRONMENTAL IMPACT ASSESSMENT FOR SUSTAINABLE DEVELOPMENT: CHITTAURGARH IRRIGATION PROJECT IN OUTER HIMALAYAS.

AMBIO, 20, 7, 1991, pp. 298-302

This study covers the Chittaurgarh irrigation project, situated in the outer Indian Himalayas. The main purpose of the study was to assess the positive and negative impacts of the ongoing project, on the physical, biological, socioeconomic and cultural environments and to ensure the continuation of natural resources.
The construction of a dam and canals have had a serious impact on flora and fauna in this project. Agricultural and grazing lands have been lost by utilization of 405 ha Himalayan forest-land upstream and 212 ha of cultivated land downstream of the project. Impacts expected after canal operation include: rise in watertable; waterlogging; increased salinity, due to clay dominated soils with low permeability, and high watertable (0.43 m) during post-monsoon period; fuelwood and fodder crises due to deforestation in the catchment area; weed infestation, crop pests; and human diseases, e.g. malaria, poliomyelitis, filariasis and goitre. Positive impacts include: flood control, increase in agricultural production (mainly rice, 25,330 t/yr-1) and improvement in socioeconomic conditions.
The investigations made on Chittaurgarh Irrigation Project clearly indicate that negative impacts are of serious concern.
The following guidelines have been proposed to eliminate the negative impacts of irrigation projects to ensure ecologically sustainable development.
- The catchment area in the watershed upstream of the dam should be afforested by mixed vegetation of native species mainly Haldu (*Adina cordifolia*), Shisham (*Dalbergia sissoo*), Khair (*Acacia catechu*), Teak (*Tectona grandis*) with good shrub cover to reduce erosion.
- Silt loads should be trapped before reaching the dam in order to eliminate sedimentation problems. The whole dam should be afforested with fast-growing trees like *Eucalyptus camadulensis* and *Eucalyptus globulus*, to absorb moisture; *Populus ciliata* for fodder and fuelwood, and *Acacia nilotica* with good cover of grasses, viz. *Cynodon dactylon*, *Vetivera zizaniodes*, *Dichanthium annulatum* for binding soil particles and checking erosion.

- The tree belt should be developed at an appropriate location on the canal embankment. Plantations should be introduced on the basis of the needs of the location. If a canal is close to a village, the tree belt should be planted to fulfil the requirements of fuelwood and fodder of the villagers. Strict regulations should be set for the cutting of trees; only mature trees should be cut. Subsidized alternative fuels should also be arranged to reduce dependence on trees. Planting trees on the canal bunds, besides yielding fuelwood and fodder, will help to suppress excessive growth of species like *Typhia augustifolia* and *Eichhornia crassipes*. The most suitable tree species are *Populus ciliata*, *Dalbergia sissoo*, and *Acacia nilotica*.
- Tanks and equalizing reservoirs should be carried out as an additional project and should be developed at appropriate locations in the area.
- Some of the low-lying swampy areas are unfit for agriculture and should be developed for fisheries. Cyprinid species are best suited for the area.
- The indiscriminate use of insecticides and fertilizers should be minimized in the project area. Integrated pest management (IPM) strategies should be popularized among farmers.
- A suitable infrastructure, involving the participation of farmers should be developed, such as irrigation cooperatives at village level for the distribution of water, at the microlevel, and for water management in general.
- Proper infrastructural facilities should be developed to meet the requirements of increased crop production which result from intensive irrigation farming. This includes farm power (electricity), seeds/seedlings, fertilizers, crop processing, storage, transport, marketing, rural credit, etc.
- Complementary education and training programs should be introduced for all professional levels involved in water management. High priority should be given to improving the understanding of decision-makers, including mid-level and senior officials, in regard to the special problems of water management. Public awareness should be improved in the villages through education of farmers and villagers.

1235

92 - 11/56

Water management
Latin America, Peru, field trials, pot trials, desert area, water use, food crops, fodder crops, alfalfa, maize, Rhodes grass, potatoes, transpiration coefficient, dry matter production, soil types, leaching of salts

ALBERDA, TH.

PRODUCTION AND WATER USE OF SEVERAL FOOD AND FODDER CROPS UNDER IRRIGATION IN THE DESERT AREA OF SOUTHWESTERN PERU.

Agricult. Res. Rep. 928, Pudoc, Wageningen; ISBN 90-220 0869X, 1984, vi + 50 p.

This report describes the results of a research project in the desert of southwestern Peru that was carried out jointly by researchers from Peru, Israel and the Netherlands.
The main purpose of the project was to investigate dry matter production and water use of the most important crops in the region under irrigated conditions and fertilizer application. To facilitate the necessary measurements and analyses, an existing laboratory was improved and measuring instruments were purchased.
In addition to field trials, pot trials were carried out, mainly to determine the transpiration coefficient (TRC), i.e. the amount of water transpired per unit of dry matter produced.
The crops mainly studied were alfalfa, maize and potatoes, which are the most important crops in the region, and Rhodes grass for comparison. All crops were sprinkler irrigated, but in a few cases trickle irrigation was used for comparison. By periodic harvesting - usually at weekly intervals - data for growth curves, the time course of the leaf area index, light interception and dry matter partitioning were compiled. In addition, the water supply to the crop was measured as well as the soil water content before and after watering. The results obtained were compared with those obtained elsewhere, sometimes also with simulation programs.
The rate of growth of an alfalfa sward varied with the season; it was higher in summer than in winter. A ceiling yield was reached earlier in the year and was more pronounced than at the end of the year. The local variety Tambo gave higher yields than the Californian variety Moapa, mainly due to higher ceiling values.
Under the prevailing conditions, fertilization with P and K was not necessary; N fertilization resulted in slightly higher yields, but without fertilization an amount of N of about 700 kg per ha per year was fixed by *Rhizobia bacteria*. No clear relation could be demonstrated between the rate of regrowth and the amount of reserve carbohydrates left in the remaining plant parts after cutting. There was a relation between regrowth in the light and in the dark, indicating that, in some way, carbohydrate reserves are important.
Maize in the project area had a slower initial growth under optimal conditions than elsewhere in the world, but in the linear phase growth rates were comparable to those in other arid zones,

leading to yields of around 25 tonnes of harvestable dry matter per ha.
Rhodes grass formed such a very dense sward that weeds were not able to penetrate. During the summer months, yields were high enough to be able to compete with other foddercrops, but during winter, growth virtually stopped, mainly due to the low night temperatures. For this reason, large scale use of Rhodes grass is not recommended on the desert plains of Peru.
Potatoes, well supplied with water and nutrients, yielded around 70 tonnes of fresh tubers per hectare - comparable to yield levels elsewhere in the world. Again the Peruvian variety yielded more than a Dutch variety, but as the latter had a more homogeneous tuber size, the marketable yield was about the same.
The relationship between the amount of dry matter produced and water received at increasing distances from a single sprinkler irrigation line was established by measurement.
For potatoes this relation was linear, almost up to the highest amount of water applied.
For alfalfa a comparable relation was found. When more than 250 mm water was applied, the crop did not show a response; below this value the relation was linear, down to about 50 mm water.
Both with alfalfa and with maize, experiments were carried out in which the amount of water applied to different plots was varied in relation to the evaporation of a Class A pan. For alfalfa, this resulted again in a rectilinear relation between dry matter production and water application up to about 250 mm water applied for both varieties and in all seasons. Application of an artificial mulch gave a better utilization of the irrigation water.
The relation between dry matter production and the amount of water evapo-transpired could be calculated from the soil water measurements.
For maize, the results were less conclusive, partly because the trial was carried out in the unfavourable season.
The highest yield was attained when water was applied at a high and constant rate for the lower plant density. Trickle irrigation instead of using sprinklers saved a considerable amount of water, however, due to the higher costs, a trickle irrigation can only be profitable if it can also be used for other crops.
Some different soil types of the pampa were tested on their water holding capacity in a lysimeter experiment with alfalfa as the test crop. When well watered and fertilized, all soils were able to give good yields. However, some soils needed to be irrigated every other day, which would require too much labour in normal practice to use them economically.
The value of the results for farming in the regions is discussed.
Author's summary, shortened.

1236 92 - 11/57

Water management
Latin America, Dominican Republic, study, on-farm project, evaluation methods, agriculture, land-tenure, land-labour relationship, irrigation systems, irrigation organization, finances, institutions, DESFIL

HANRAHAN, M. et al.

EVALUATION OF THE ON-FARM WATER MANAGEMENT PROJECT IN THE DOMINICAN REPUBLIC.

Publ. of Development Strategies for Fragile Lands, 7250 Woodmont Avenue, Suite 200, Bethesda, Maryland 20814, USA; 1990, 67 p. + appendix

This report documents a fundamental change in the institutional arrangements for irrigation management in two large irrigation systems in the Dominican Republic.
The On-Farm Water Management Project (OFWMP), sponsored by the U.S. Agency for International Development, was implemented with the Instituto Nacional de Recursos Hidraulicos (INDRHI) of the Dominican Republic. The project sought to strengthen INDRHI capacity to plan for and to manage irrigation systems, to increase irrigated agricultural productivity, and to improve lands affected by waterlogging. The two project areas, Azua (YSURA) and Santiago (PRYN Contract I), total 14,400 hectares, and serve 6,000 farm families.
To accomplish project objectives, the OFWMP made physical improvements to the two irrigation systems, assisted in formation of local organizations to manage the irrigation systems, and facilitated turnover - the transfer of responsibility for system operations and maintenance (O&M) from a public sector agency to private sector associations known locally as Juntas de Regantes. These three steps are linked. Major rehabilitation of facilities coupled with organization of farmers enabled turnover to succeed.
Recommendations have been made by the evaluation team:
The evaluators recommend that, in their initial years of operation, the Juntas Directivas concentrate their human and financial resources on a core set of functions.
These functions should be defined and carried out with the full, democratic participation of farmers.
The Juntas Directivas have shown interest in activities beyond core functions. Examples include marketing, credit, and agricultural extension. These activities are compelling and reflect legitimate and urgent farmer concerns. However, at least in the early and financially uncertain years, the evaluators recommend that the juntas generally restrict such activities because it will spread too thinly the limited financial resources and managerial capacity of the juntas.
Perhaps the greatest accomplishment of the project has been to deliver water reliably to a large number of tail-end farmers in the two systems. But the project has not established ways to

monitor actual water flows to the various parts of the systems and to compare these with allocated amounts. The project should obtain measurements of water delivery equity.
The expenditure of remaining OFWMP funds for pilot area development would be detrimental to organizational efforts and should be a low-priority item. Money spent in pilot areas could be used to rehabilitate portions of the systems that are in disrepair or not completed. This could attract additional farmers into joining the juntas and paying fees. Further work on construction in pilot areas should be halted. Decisions regarding future construction work in pilot and other areas should be made with participation of the juntas.
In future assistance to the Dominican irrigation sector, USAID should take a proactive stance concerning the sustainable use of natural resources. The evaluators recommend that USAID allocate funds for the study of project side-effects, such as increased pesticide use, and use the results of these studies and other accumulated knowledge to program requisite abatement technologies into future assistance to the Dominican irrigation sector. Sustainable environment and natural resource management is not contradictory to the goal of rural income generation or to resource use. Sustainable, resource-conserving, and income-enhancing technologies for soil and water use exist and, under Agency policy, should be used.
As experience in the Dominican Republic shows, irrigated agriculture may be associated with potential negative environmental impacts. Misuse of irrigation water can result in significant declines in the productivity of land and water resources through soil erosion, waterlogging, and salinization. Agricultural inputs may be indiscriminately applied, and can lead to build-up of resistant pest populations and toxic chemical residues and to runoff.

XII SOIL FERTILITY

1237 92 - 12/63

Soil fertility
Review, tropics, symposium, soil fertility, plant production, soil constraints, sustainability

TARC

SOIL CONSTRAINTS ON SUSTAINABLE PLANT PRODUCTION IN THE TROPICS.

Trop. Agric. Res. Series No. 24; Trop. Agric. Res. Center (TARC), Tsukuba, Ibaraki, 305 Japan; ISSN 0388-9386, 1991, 216 pp.

Generally it is recognized that the tropical and sub-tropical countries and regions are faced with various kinds of soil constraints on sustainable plant production in cultivated lands, pastures and agroforestry schemes, which are presumably caused by fertility, acidity and salinity, erosion, micronutrient deficiency or excess, physical, chemical and biological limitations.
On behalf of the Symposium Organizing Committee of the Tropical Agriculture Research Center (TARC), the "International Symposium on Soil Constraints on Sustainable Plant Production in the Tropics" under the co-sponsorship of the TARC, Ministry of Agriculture, Forestry and Fisheries, Japan, was held.
The TARC was established in 1970 with the objective of contributing to the development of agricultural technology in the tropical areas in undertaking research programs.
The TARC activities cover a fairly wide range of research fields such as crop production, soil and water management, plant protection, pasture and animal husbandry, agriculture and food engineering, forestry and agroforestry.
In the symposium discussed here, the causes of the constraints are evaluated based on scientific data. The establishment of relevant measures for their alleviation with emphasis placed on low-input and sustainable plant production, in taking account of the preservation of the co-systems and environment in the tropics and sub-tropics are discussed.
This book is organized in country reports, technical reports and closes with a general discussion.
The book provides an overview of soil-based constraints which are limiting the sustained productivity of agriculture. It covers the research activities on characterization, genesis and amelioration of soil-related physical, chemical, and biological constraints. Some of the constraints are natural whereas others have arisen due to human interventions. Waterlogging and salinization in irrigation commands of arid and semi-arid regions, overmining of nutrients, and excessive exploitation of underground fresh waters have decreased the productivity of crops in several regions of the tropics. Alternative methods of soil management for improvement of degraded land qualities, and maintenance of environment and productivity of the soil resources are discussed.

1238 92 - 12/64

Soil fertility
Europe, review, soil pollution, agricultural practices, plant nutrients, fertilizer, pesticides, animal excreta, water athmosphere

PAIN, B. et al.

IMPACT OF AGRICULTURAL PRACTICES ON SOIL POLLUTION.

Outlook on agriculture, 20, 3, 1991, pp. 153-160

There is a growing appreciation of the need to preserve soils and their chemical status.
There is an urgent requirement to understand and quantify the various inputs and outputs in order to devise protection policies for this key resource.
This paper focuses on the problems that result from high inputs of plant nutrients, from fertilizers or animal excreta, and from the pesticides that are associated with intensive production. Concern is not only about the direct effects on soils but also on leakages to both water and the atmosphere.
Soils are the base resource for food production.
Their physical and chemical properties are wide-ranging, allowing them to act as sinks or sources in complicated cycles and buffer changes in the flows of materials to other compartments of the ecosystem.
Man's activities can disturb the equilibria involved through
- manufacturing and energy-related activities, resulting in atmosheric inputs of sulphate, acidity, nitrogen (N) and trace metals, for example, or indeed accidental inputs of radio-nucleides,
- urbanization, resulting in direct losses or changes due to recreational activities and
- agricultural manipulations.

The effects of agriculture can be physical, induced by mechanically working the soil in an inappropriate way to result in, for example, soil compaction or erosion, or they may be chemical.
This article is concerned with some of the problems associated with chemical changes.
In detail, the effects of fertilizers, slurries and manures from housed livestock and pesticides are discussed.

1239 92 - 12/65

Soil fertility
USA, field study, greenhouse study, organic biostimulants, low-input agriculture, forestry, horticulture, plant growth, stress resistance, fertilizer application, organic agriculture

RUSSO, R.O. and G.P. BERLYN

THE USE OF ORGANIC BIOSTIMULANTS TO HELP LOW INPUT SUSTAINABLE AGRICULTURE.

Journal of Sustainable Agriculture, 1, (2), 1991, pp. 19-42

Organic farming maintains soil quality better and reduces contamination of air, water, soil, and final food products, but much research is needed to determine how to maximize the integration of organic practices.
Methods of increasing fertilizer efficiency must be investigated.
The approach to increasing crop productivity is the development of non-polluting organic biostimulants. These compounds increase plant growth and vigor through increased efficiency of nutrient and water uptake. Definitions for biostimulants vary greatly and there are still some arguments surrounding these compounds. However they are defined as on-fertilizer products which have a beneficial effect on plant growth. Many of these biostimulant materials are natural products that contain no added chemicals or synthetic plant growth regulators. The initial empirical image of these compounds is changing.
An overview of some of the individual components of the biostimulant blend is given in this paper.
Studies were aimed to test different concentrations (dilutions) of the biostimulant.
Research at the Yale University School of Forestry and Environmental Studies has developed, a new biostimulant (ROOTS). The product consists of a mix of humic acids, algae extracts, a non-hormonal reductant plant metabolite, and vitamins. This blend greatly increases root and top growth of plants, while decreasing fertilizer requirements up to 50% in a number of species (coffee, several grass species, pines, Douglas-fir, Gliricidia). The biostimulant also increases resistance to low soil water potential and possibly residual herbicides in soil.
The organic biostimulant, ROOTS, seems to offer a significant opportunity to increase plant growth, according to findings from current university research and field trials. Improved root and shoot growth, better root growth potential, and better stress resistance seem to be consistent with other results. The most important possibility for the future of this organic biostimulant, may be its ability to cut down chemical fertilizer without affecting growth. Preliminary research showed that in the presence of the biostimulant, coffee seedlings treated with the half amount of fertilizer yielded the same shoot biomass and higher root biomass than those fully fertilized.

1240 92 - 12/66

Soil fertility
Europe, Netherlands, field study, high input agriculture, low external input agriculture, nitrogen cycling, nitrogen balance, nitrogen mineralization, nitrogen immobilization, denitrification, microbial biomass

VAN FASSEN, H.G. and G. LEBBINK

NITROGEN CYCLING IN HIGH-INPUT VERSUS REDUCED-INPUT ARABLE FARMING.

Netherlands J. of Agric. Sc., 38, 1990, pp. 265-282

In this paper, N_1-balance calculations covering the growing season will be discussed as well as changes in soil N mineralization rate, in N uptake by the crop, and in N losses due to changes in management. A conventional farming system was compared with two integrated systems, each system with the same rotation of winter wheat, sugar beet, spring barley and potatoes on a silt loam soil. Soil physical conditions and meteorological data necessary to account for some of the differences in overall N budget are discussed.
Field work was carried out at an experimental farm on a calcareous silt loam soil.
A previous experiment at the experimental site, in which three different input regimes of organic matter were compared, was taken as a starting point.
Agroecosystems are inherently more 'leaky' than undisturbed natural ecosystems where vegetation is continuously present. Increased inputs of nitrogen into agriculture have greatly increased crop (N) outputs, but they have also increased N losses to the environment.
Integrated management might give lower crop yields than conventional management, but because of lower costs, the profitability to the farmer could be similar.
Nitrogen balance sheets for the growing seasons of 1986-1988 showed N deficits of 0-170 kg ha^{-1}, suggesting substantial N losses to the environment.
The uncertainty about actual N losses mainly depended on the uncertainty of estimated net N mineralization. Periods with much rainfall in 1987 and 1988, inappropriate use of animal manure and soil compaction may partly account for the heavy N losses in all farming systems. Potential rates of N-cycle processes were studied over the years to observe effects of changes in management.
The following conclusions can be drawn from these studies:
- The uncertainty about actual N losses mainly depended on the uncertainty in the calculated net N mineralization for field conditions. Especially uncertain was the contribution of the layer 40-100 cm, with a rather high organic matter content, to N supply of the crops.
- The soil organic matter and total-N contents showed a tendency to differentiate from their original two levels, into four

levels as a result of changes in management. The next years will show which new steady-state levels will eventually result from integrated or conventional management.
- Correlations between N mineralization rates and biomass-N flush of soil samples were found to be situation-dependent.
- On fields with initial organic matter levels of 2.2% and 2.7%, crop yields under integrated management were on average 83% and 88%, respectively, of crop yields under conventional management.
- In the integrated system, the spring application of pig manure had to be changed to autumn application of spent mushroom compost, to prevent N loss by NH_3 volatilization and by denitrification. The use of compost is also needed to maintain a high level of soil organic N.
- To minimize the risk of N losses to the environment, soil inorganic N concentrations should be kept low, especially in periods when no active crop is present and N losses are most likely to occur.

1241 92 - 12/67

Soil fertility
Review, symposium, rice farming, green manure, cropping systems

IRRI

GREEN MANURE IN RICE FARMING.

Publ. of the International Rice Research Institute, Los Banos, Philippines, 1988, 378 pp., USD 12.30

This book embodies the proceedings of a symposium on sustainable agriculture held in 1987, at the International Rice Research Institute (IRRI), Los Banos, Philippines.
Some 92 scientists from over the world participated in the conference.
Topics include the use of green manures in China, southern Asia, parts of Africa, USA and other areas, as well as topics on woody species, N transformation, soil redox dynamics, and others dealing with general principles.
This book contains a wealth of valuable information on perennial and annual legumes as a N source and for soil improvement in upland and lowland rice production. Basic concepts and practical applications are covered well.
Discussion of N transformation, crop uptake, losses and residual is handled in an thorough manner.
Several of the writers pointed out, the value of green manuring is greater than N supply per se, e.g., several physical and chemical properties are also modified beneficially.
Contributions of N by food-crop grain and food-crop legumes were presented as an important consideration, since the economics of appropriating land and time for N production is often not cost effective due to the cost constraints of labour, land opportunity and seeds. These constraints forced a steep decline in the use of green manures in rice production everywhere as N fertilizer became available and affordable.
The first chapter of the book, nine pages, consists of the recommendations that emerged from the symposium discussions, including research needs and proposed research areas.
Advantages und disadvantages of green manure use are listed.
The papers and discussions during the symposium reconfirmed that - broadly defined - green manure does increase rice yields. Moreover, empirical evidence and theoretical considerations strongly suggest that green manure can contribute to the sustainability of tropical agricultural systems in which rice is a major crop.
The information is presented in 25, generally well-written, edited and documented chapters.
The book is a valuable resource and the information is presented interestingly.
It is an excellent reference to those involved in rice production and possibly a textbook in courses in soil management and sustainable agriculture, especially looking to the future.

1242 92 - 12/68

Soil fertility
Africa, Nigeria, humid tropics, field trials, maize, cassava, low-input agriculture, green manure, IRRI

VAN DER HEIDE, J.

ROLE OF GREEN MANURE IN LOW-INPUT FARMING IN THE HUMID TROPICS.

In: Green Manure in Rice Farming; Proc. of a Symp. on Sust. Agriculture, IRRI, Philippines, 1988, pp. 186-191

The use of cover crops is particularly relevant in the humid tropics, as high rainfall generally has depleted the soil of nutrients, especially nitrogen, which leaches easily. Levels of soil-organic matter are generally low, and there is a rapid and persisting weed growth, which is one of the main reasons why farmers have to abandon their plots.
Cover crops have been used for a long time by small farmers in the tropics in their crop rotations, mostly as a cheap source of biologically fixed nitrogen, for the recycling of leached nutrients, for protection against erosion, for the build-up and maintenance of soil organic matter and for the suppression of weeds.
Field experiments under humid tropical conditions in southeastern Nigeria for several years studied N requirement and utilization of upland cropping systems, with and without legumes and with low-input management on acid, low-activity clay soils. Total N utilization over several cropping systems was assessed. Quantities of N removed from the soil and left behind as crop residues after harvest and residual effects of N fertilizers and legumes included in the cropping systems were determined.
Although the data presented were obtained in the first years of a long-term experiment, the results indicate that, from the first year after clearing, considerable differences occur in N use and conservation of intercropped or sequentially cropped systems of non-irrigated agriculture in the humid tropics. In three of the four systems studied, more N was removed by harvest products than was returned after harvest with the crop residue, even at the high N fertilizer levels applied in the experiment. This also occurred if pigeonpea or cowpea were included in the cropping system.
A green manure planted after monocropped maize in the second season did not have a significant effect on yield of the following maize crop compared to cowpea, substantially more nitrogen was returned to the plot than was removed by harvest products.
After continuous cropping for 4 yr, the inclusion of a legume in the crop rotation, in particular as a second season cover crop, showed an important residual effect on N supply to monocropped maize. No residual effects were observed from N fertilizer applications.
Cassava utilizes substantial amounts of fertilizer N. Removal of stems from the field after harvest removes large quantities of N from the cropping system. After the basic requirement of cuttings

has been satisfied, ways should be found to restore the N in the stems to the soil without harmful side effects. Including a green manure in traditional cropping systems appears to be the best alternative to attain sustained crop production in low-input agriculture, as far as the supply of N is concerned.
Including a green manure crop such as mucuna in the minor season did not result in better performance of maize than of second season cowpea, but did have a pronounced residual effect on the succeeding maize crop.
Detailed studies on the relationship between the inclusion of cover crops and the buildup and maintenance of soil organic matter, and the processes that control the availability of plant nutrients in the low-activity clay soils in the humid tropics are needed.
Since many green manures cannot be used for human consumption, other benefits should become obvious to the farmer after one or two cropping cycles. Grain legumes, although providing immediate economic benefit, tend to accumulate nutrients in the grain which is harvested, so that their effect on the performance of the following crop is usually low.
Nitrogen-fixing cover crops can be an excellent way to supply a substantial quantity of nitrogen and recycled nutrients to the annual crop rotation, by returning the total biomass produced to the soil, just before planting one, or a combination of food crops in the following season. Leguminous forage crops to provide feed for cattle can have a double function.

1243

92 - 12/69

Soil fertility
Africa, Rwanda, highlands, acid soils, field trials, beans, wheat, vetch, green manuring, yield, soil fertility, FSRP

YAMOAH, C.F. et al.

GREEN MANURING WITH VETCH ON ACID SOIL IN THE HIGHLAND REGION OF RWANDA.

Biol. Agric. and Hort., 7, 1991, pp. 303-310

The purpose of this study is to assess the value of vetch used as a green manure crop on acid soil prevalent in the highland region of Rwanda. Bean (*Phaseolus vulgaris*) and wheat (*Triticum aestivum*) yields and soil chemical analysis following incorporation of vetch were used to evaluate success in the improvement of soil fertility.
The study was carried out during four cropping seasons.
The soils are classified in the USDA system as Oxisols.
The advantages ascribed to legume green manuring are numerous and include: improvement in soil fertility, increased cation exchange capacity, increased water retention, enhanced microbial activity and improved soil structure.
Vetch (*Vicia sativa* L.) is a potential green manure crop in the East-Central African highland region where soils are generally acidic. In this area, vetch grows relatively fast, assumes a quick soil cover to check ground erosion and produces high biomass.
Incorporation of 5-month old vetch lowered soil pH as well as raising exchangeable Al and H and reducing exchangeable Ca, Mg, and P. Consequently, bean and wheat yields for the subsequent season were reduced by 71 and 33%, respectively. There was no response to fertilizer N on either main treatment. There were no significant yield differences for either crop with respect to vetch treatment during the second season. Third season crop yields were superior on the control plot, with that of beans being significantly different. Application of lime raised exchangeable Ca, K and reduced exchangeable Al. Bean was more affected by exchangeable Al than wheat. Half-life for decomposition of the vetch was 3.5 weeks and nutrient release pattern followed the order: K>N>P>Ca indicating that liming may be required to supply Ca and to neutralize soil acidity at the initial stages of decomposition.
Concluding, it can be stated that in the Rwandan highlands vetch grows rapidly and provides a quick cover to control erosion. Its use for green manuring on the acid soils in this region must be treated with caution. Decomposing vetch material initially made the soil acidic and crops which immediately followed vetch incorporation suffered severe yield losses. It may be advisable to allow three to four weeks after incorporation before seeding food crops. Similarly, lime application may be necessary to counteract adverse effects of soil acidity during early stages of decomposition and also to supply Ca.

1244 92 - 12/70

Soil fertility
Asia, Philippines, humid tropics, lowland, field experiment, cropping systems, preceding crops, organic manure, nitrogen fertilizer, mungbean, sesbania, green manure, rice, maize, yield, residual effects

MEELU, O.P. et al.

TROPICAL LOWLAND RICE RESPONSE TO PRECEDING CROPS, ORGANIC MANURES AND NITROGEN FERTILIZER.

Trop. Agric. (Trinidad), 69, 1, 1992, pp. 96-100

This study determined the effects of alternative crops grown late in the dry season on fertilizer N response of wet season irrigated rice and residual effects on dry season irrigated maize.
The experiment was initiated in 1984 on the farm of the International Rice Research Institute, Philippines, and repeated in 1985.
Five cropping sequences were examined:
- Green manure (*Sesbania cannabina* [Retz] Poir)
- rice (*Oryza sativa* L.)
- maize (*Zea mays* L.)
- Fallow [farmyard manure (FYM)] - rice - maize;
- Fallow - rice - maize;
- Mungbean (*Vigna radiata* [L.] Wilczek) - rice - maize; and
- Maize fodder - rice - maize.

The experiment was laid out in a strip plot design with strips of crops in one direction and strips of N levels in the other. The treatments were replicated four times. Crop sequence and N level strips were re-randomized for each of the four replicates.
The soil of the experimental field was clay.
Mean rice grain yield without fertilizer N was maximum (4.5 t ha^{-1}) after *Sesbania* and minimum 2.7 t ha^{-1}) after maize fodder. Mean yields of unfertilized rice after FYM, fallow, and mungbean were intermediate, decreasing in that order. Yields of unfertilized rice grown after *Sesbania*, the aboveground biomass of which accumulated 70 kg N ha^{-1} (1984) and 98 kg ha^{-1} (1985) in 60 days were comparable with rice yields in fallow plots to which 44 and 96 kg ha^{-1} fertilizer N, respectively, were applied. FYM (15 t ha^{-1}) supplied 68 kg N. The efficiency of N from FYM in combination with different N levels on rice ranged 31-51%. Significant residual effects of FYM and green manure on the succeeding maize crop were not detected. Soil organic C and total N after wet season rice in 1985 were higher when *Sesbania* and FYM preceded rice compared with maize fodder, mungbean or fallow.
Crops in the tropics are often grown in a particular sequence. Fertilizers and manures applied to one crop can affect the response of the succeeding crop.
To estimate optimum N fertilizer rates for crops grown in sequence, the effects of the preceding crop species and application of farmyard and green manures should be considered..

1245 92 - 12/71

Soil fertility
Africa, Niger, semi-arid tropics, drylands, farm practices, field trials, pearl millet, cowpea, intercropping, soil fertility, crop productivity

REDDY, K.C. et al.

PEARL MILLET AND COWPEA YIELDS IN SOLE AND INTERCROP SYSTEMS, AND THEIR AFTER-EFFECTS ON SOIL AND CROP PRODUCTIVITY.

Field Crops Res., 28, 1992, pp. 315-326

The objective of this study was to compare the productivity and effects on soil fertility by rotations of these common crops in Niger.
A 4-year field experiment was conducted in a Psammentic Paleustalf in Niger to determine the continuous cropping effects of pearl millet (*Pennisetum glaucum* (L) R.Br.), cowpea (Vigna unguiculata (L.) Walp.) and three pearl-millet/cowpea intercrop systems with cowpea planted 1, 2, and 8 weeks after millet planting on soil and crop productivity. Crops were grown for grain on the same plots under rainfed conditions in 1986, 1987 and 1988 crop seasons and all crop residues were removed from experimental plots.
For three years preceding the experiment, millet was continuously planted in association with cowpea at low densities on these plots, similar to much of the dryland farm practices in Niger.
It can be concluded that millet/cowpea intercrop systems showed better land-use efficiency than sole millet or cowpea systems. On a total grain-yield basis, sole cowpea was more productive. Continuous cropping of sole cowpea with residue removal significantly increased soil Mg and OM over sole millet or millet/cowpea intercrops. Test-crop millet produced significantly higher dry-matter yield and N uptake in PCS sole cowpea than other treatments. Test-crop millet N uptake after previous intercrop treatments was significantly greater than previous sole millet. This leads us to believe that cowpea inclusion in sole or intercrop systems would make extra soil N available to following cereal crops such as millet. From a practical point of view, introduction of sole cowpea or cowpea-based intercrop systems in place of traditional millet-dominated intercrop systems may be advantageous.
Pearl millet (*Pennisetum glaucum* (L.) R.Br.) is planted principally for grain on about 10 million ha in West Africa. Generally in this region, millet is grown on infertile sandy soils in association with cereals such as sorghum and/or with legumes such as cowpea or groundnuts. Of all the combinations, the millet/cowpea association is the most widely used in the Sahelian zone of Niger, extending up to 50% of the country's cultivated area (about 2 million ha).
In recent years, farmers in Niger and other West African countries increased land area under millet cultivation to meet food needs by effectively decreasing the fallow period or replacing the

traditional shifting cultivation with continuous cropping of millet-dominated intercrop systems.
As the application of fertilizers is not always economical in the semi-arid tropics of Niger, non-fertilizer-based methods to improve soil conditions, such as legume use, deserve special attention. In spite of a tremendous knowledge base in this area from Asian and Western countries, crop rotation on the impoverished soils of West Africa is not practiced. This and other improper cultural practices are leading to a large-scale degradation of soils in this area.

1246 92 - 12/72

Soil fertility
Latin America, Colombia, field trial, phosphorus availability, bean seed tolerance, seedlings, mineral deficiences, roots, leaves, stems, starch, content, protein content, CIAT

SADEGHIAN, K.S.

Infuencia de algunas caracteristicas de las semillas y plantulas de frijol *Phaseolus vulgaris* L. sobre la tolerancia a la baja disponibilidad de fósforo en el suelo (Influence of some characteristics of bean seed and seedlings on the tolerance to low phosphorus availability in the soil).

Tesis Universidad Nacional de Colombia, Bogota, Colombia; Ing. Agr. Palmira: 1991, 81 pp.

The influence of certain quantitative characteristics of bean seed on the capacity of seedlings to tolerate low available P in the soil was determined. The starch, protein, phytic acid, and different P fractions of the seed were determined in 23 bean genotypes during the 1th phase of research. Results indicated that the reduction in total biomass production of the seedling and in tissue P concentration was pronounced at 16 days after planting, as a direct consequence of soil P deficiency. However, this reduction was more pronounced in the leaves since a greater amount of photosynthates were invested in root production, thus increasing the relative extension of the root system in the soil. The no. of main roots proved to be a variety characteristic that is unmodified by soil P levels. On the other hand, the size of endodermical cells was significantly increased by the low P treatment, possibly due to a nutritional physiological adaptation mechanism; however, no significant differences were found among variety. Seed weight and size of cotyledon cells showed a positive, highly significant correlation with seedling vigor. The coefficients of correlation obtained in the low P treatment were higher than those of the high P treatment, indicating that the nutritional dependence of the seedlings is more pronounced under P deficiency conditions. Variance analysis showed that cotyledon reserves satisfied the nutritional needs of the seedlings more less up to 12 days after planting, after which significant differences in growth rates occurred. Although total biomass production was directly related to seed size, it did not affect the duration of reserves. Although the experiments attempted to minimize the variations existing between environments (pots and tubes) and between replications, statistical analysis revealed significant differences due to these factors. Root analysis in modified PVC tubes was useful in the study of overall genotype performance, but maladjustments occurred that affected the final results of P treatment.