Improving management of natural resources for sustainable rainfed agriculture

Proceedings of the traveling workshop-cum-field visit to benchmark watersheds

27 August to 12 September 2000

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About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the SAT. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Program (UNEP), and the World Bank.

Improving Management of Natural Resources for Sustainable Rainfed Agriculture

Proceedings of the
Traveling Workshop-cum-Field Visit to Benchmark Watersheds

27 August to 12 September 2000

Editors
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Workshop Committee

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Executive Summary

Workshop overview

A traveling workshop-cum-field visit to the benchmark watersheds was organized from 27 August to 12 September 2000 under the Asian Development Bank (ADB) Project "Improving Management of Natural Resources for Sustainable Rainfed Agriculture". The Workshop included the travel of the participants for 15 days to three countries (India, Vietnam, and Thailand) in Asia to learn about eight watersheds, of which three are on-station watersheds and five are on-farm watersheds.

Dr T D Long welcomed the participants to Vietnam. He enlightened the participants about Vietnamese agriculture. He briefed about the challenges of development in the sloping land ecoregions of northern Vietnam. He said that the nation has now attained a self-sufficiency status from a self-insufficiency stage. Land and water management is the urgent need to conserve the natural resources, which are neglected for a long time. He explained that the watershed framework in the sloping ecoregions of northern Vietnam constituted complex agro-ecologies which will lead to diversified high agricultural production and control of environmental degradation; this provides a mechanism for the recharge of groundwater aquifers. He expressed that it is a good opportunity for him and his fellow scientists to interact and exchange views with the scientists from other countries. He also said that "cross fertilization" of views will enrich the knowledge for better planning of research for sustained agricultural growth and natural resource management (NRM).

Objectives and structure of the workshop

Dr S P Wani gave a brief note on the objectives and structure of the workshop. He thanked Dr T D Long for enlightening the participants about Vietnamese agriculture and for giving an in-depth knowledge about NRM in Vietnam. He gave a brief report on the major constraints for sustaining productivity in the semi-arid tropics (SAT) agro-ecosystem on which the objectives of the project are framed. The overall objective of the present workshop is to appraise all the partners in the three countries, India, Thailand, and Vietnam, with the research work going on at all the locations in on-farm and on-station watersheds and to give suggestions for further improvement of the watershed-based research in their respective countries.

The workshop was formulated as an opportunity for all of the scientists to take advantage of the extensive research efforts and information. The participants had a chance to analyze the situations of the watersheds at the same time as a chain of events during a span of 15 days.

Recommendations

The eclectic group of scientists made a series of suggestions and observations at the end of the workshop. Each participant was provided with a questionnaire with 25 queries on different aspects of watershed activities such as soil and water conservation measures, integrated nutrient management (INM), integrated pest management (IPM), and farmers' participation in implementation of projects. Each watershed was evaluated by the participants and a set of suggestions were given for the individual benchmark watershed by a particular scientist and the "take home" activities to be implemented in their watershed area were noted down by all the scientists. Participants were asked to respond to the queries and evaluate on 1–5 rating scale where <3 indicates needs improvement; 3–4 good; and >4 excellent. A short summary of all the individual evaluations was prepared and it will be useful for the participants themselves in the improvement of watershed activities in their area of operation.

Implementation strategy

The final goal of the workshop is to achieve a 'motivational tool' for implementing the recommendations that come out of the discussions. Overall the workshop encouraged the scientists to learn from each other through discussions and suggestions for implementing in their respective watersheds and to infuse new innovations into the project.

In the summary of evaluations, scientists identified benchmark sites from which new things were learnt. They identified on-farm Adarsha watershed (Kothapally, India) and on-station BW7 watershed of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (Patancheru, India) as model watersheds and aspects that could be improved in each watershed were emphasized. The need for strengthening farmers' participation in two on-farm watersheds, Tad Fa (Thailand) and Ringnodia (Madhya Pradesh, India), was highlighted. In conclusion the workshop helped significantly all the project partners and offered suggestions for mid-course corrections in the benchmark watersheds.

Inaugural Address

A very good morning and warm welcome to all the Traveling Workshop-cum-Field Visit participants. I wish you all a pleasant and productive stay in Vietnam. For the benefit of those visiting Vietnam for the first time, I would like to provide a bird's eye view about Vietnam's agriculture. Vietnam is located in Southeast Asia in the Indo-China Peninsula bordering Mainland China in the north, Laos and Cambodia in the west, the East Sea in the east and south. Its geographical position is from 8° 45′ to 23° 22′ N and 102° 08′ to 109° 30′ E. The natural area is 33099 km^2 with an arable area of 7.3 million ha occupying about 22% of natural area. Population density is high with 214 persons km^{-2} while agricultural land per capita is lowest in the world (1000 m^2 for upland crops and 600 m^2 for rice).

Vietnam is primarily an agricultural country. Agriculture plays a vital role in the national economy and contributes 30% grass domestic product (GDP) and 40% total export earnings. Vietnam lies in the region of monsoon, tropical weather with high temperature. Annual rainfall ranges between 1800 and 2000 mm with uneven distribution. Droughts in dry season and floods in rainy season are common. Versatile and various climates in different regions provide opportunity for variety of vegetation and animals. Rice is the most important crop and cultivated in 7.52 million ha with an output of 31.5 million t of paddy rice. Maize ranks second with 800,000 ha and 2 million t production. Cassava, groundnut, and sweet potato are the other major crops. Legumes and vegetables occupy 662,200 ha with a production of 8 million t.

Challenges of development in the sloping land ecoregions of northern Vietnam

In the past 12 years, the renovation policy "*Doi moi*" together with extension of improved production technologies in agriculture has brought the nation from being food insufficient to food self-sufficiency status. The GDP has grown at an average rate of 6–8% in recent years. Rapid growth was achieved through liberalization and structural reforms. However, most of these achievements are confined to well-endowed environments like Red River and Mekon Delta. Currently, the government of Vietnam is placing higher emphasis on upland areas for agricultural and rural development. The rainfed sloping lands compose approximately one-third of the land area of northern Vietnam with unsustainable production practices leading to resource degradation. The key constraints in these ecoregions are remoteness and inaccessibility, low biological productivity, environmental degradation, disease and health problems, population increase, ethnic relations, and the lack of a development paradigm tailored to the special conditions.

The conservation of land and water resources has been neglected for too long. There is an urgent need for development of sustainable land and water management strategies suitable for these ecoregions. Focus on micro-level land and water will help optimize food production and contain land degradation. The landscape watersheds in the sloping ecoregions of northern Vietnam constitute complex agroecologies. It is made up of a combination of upland and lowland ecologies or a toposequential complex of ecologies representing upland, lowland, and a coastal ecosystem. The watershed framework, therefore, can provide necessary inter-ecological linkages and is a logical unit for the integration of the sustainable use of land and water. It can also enjoin the biophysical, social, and economic inputs for optimal management, lead to diversified high agricultural production and control of environmental degradation, and provide a mechanism for the recharge of groundwater aquifers.

It is with this background, the Vietnam Agricultural Science Institute (VASI) joined hands with ICRISAT to develop eco-environment friendly resource management practices that will conserve soil and water resources and increase and sustain the productivity of sloping land ecosystems of northern Vietnam. The Regional Technical Assistance (RETA # 5812) of the ADB on “Improving Management of Natural Resources for Sustainable Rainfed Agriculture” is a great help to accelerate the pace of research efforts in NRM.

Watershed-based technologies offer excellent opportunities for sustainable land and water development in sloping land ecoregions. In the coming years, the strategic goal is sustainable eco-agricultural development in the sloping land ecoregions through new crops and cropping systems to make cultivation more profitable; agroforestry in the higher elevations of the toposequence to arrest erosion; and horticulture and animal husbandry to raise the household economy.

VASI is making concerted efforts to mitigate the constraints in the sloping land ecoregions and develop appropriate techniques for sustainable agriculture through close cooperation with various national and international institutions.

I consider this traveling workshop quite important as it provides good opportunity to me and my colleagues to interact and exchange views with other project scientists from India and Thailand as cross fertilization of views and research experiences always helps enrich our knowledge and thereby help plan better research for sustained agricultural growth and NRM. I thank ICRISAT management for selecting Vietnam as the starting point and VASI as the venue for inauguration of this important event. I wish you all great success, and a productive and memorable stay in Vietnam.

T D Long
Deputy Director General
Vietnam Agricultural Science Institute (VASI)

Objectives and Structure of the Workshop

Good morning Dr Long, other VASI officials and delegates of the Traveling Workshop-cum-Field Visit. On behalf of ICRISAT and on my own behalf, I extend you a warm welcome to this workshop which is inaugurated in Vietnam. I would like to brief you about the project in general and then go along with you over the objectives and the strategy of this workshop. Thank you Dr Long for providing a very good overview and introduction to Vietnam agriculture in general and also for providing in depth information about the NRM work done at the benchmark site in Vietnam.

The project "Improving Management of Natural Resources for Sustainable Rainfed Agriculture" is funded by ADB to enhance research and development efforts to improve management of natural resources for sustainable rainfed agriculture in three participating countries—India, Thailand, and Vietnam.

Before knowing the specific objectives of the project and the present workshop, a brief note on the major constraints for sustaining productivity in the SAT agro-ecosystems is given on which the objectives are framed. Insufficient soil moisture, low fertility, lack of improved stress tolerant varieties, pests and diseases, inappropriate soil, water, and nutrient management (SWNM) practices, and finally environmental degradation are the major constraints in the SAT agro-ecosystems. Degradation of natural resources in Asia has reached an alarming situation and is the main cause of concern for sustaining productivity and protecting the environment. Taking all the above constraints into consideration in this project we have adopted an integrated watershed approach to efficiently manage the natural resources such as soil, water, vegetation, and climate.

Salient characteristics of the project

- The project addresses the issue of natural resources and targets efficient use of resources for sustaining productivity while minimizing land degradation.
- It targets a medium rainfall ecoregion characterized with medium to high water-holding capacity soils. A concept of benchmark sites for undertaking research and development is adopted in the region.
- It is operating at five on-farm and three on-station benchmark watersheds in India, Thailand, and Vietnam.

On-farm watersheds

1. Thanh Ha watershed, Hoa Binh Province, Vietnam
2. Tad Fa watershed, Region 3, Khon kaen, Thailand
3. Ringnodia watershed, Madhya Pradesh, India
4. Lalatora watershed, Madhya Pradesh, India
5. Adarsha watershed, Andhra Pradesh, India

On-station watersheds

1. Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV) watershed, Indore, Madhya Pradesh, India
2. Indian Institute of Soil Science (IISS) watershed, Bhopal, Madhya Pradesh, India

3. BW7 watershed, ICRISAT, Patancheru, Andhra Pradesh, India

- The project follows a holistic systems approach and all on-farm research is done in participatory mode with the farmers.
- Developmental research is supported with strategic research and benchmark watersheds are technically supported.
- A multidisciplinary team of scientists work together in a multi-institutional consortium to address the complex issue of efficient use of natural resources.
- More emphasis is on empowerment of farmers and the national agricultural research systems (NARS).
- New science tools such as geographical information system (GIS), simulation modeling and satellite imageries are used for efficient use of natural resources and also for assessing the impact of NRM research to sensitize the policy makers.

Project objectives

The objectives of the project are to:

- Increase the productivity and sustainability of the medium and high water-holding capacity soils in the intermediate rainfall (800–1300 mm) ecoregion; and
- Develop environment-friendly resource management practices that will conserve soil and water resources.

To achieve these objectives, we have selected benchmark sites representing the target ecoregion in the three participating countries. As you are aware that all the eight benchmark sites were established in the first year of the project and integrated SWNM research is conducted in these watersheds. The overall objective of this Traveling Workshop-cum-Field Visit is to appraise all the partners from three countries with the research work going on at each location and offer suggestions to improve it further. This being the second year of the project mid-course corrections at all the benchmark watersheds can be done based on the suggestions from you all.

Workshop objectives

The specific objectives of this workshop are to:

- Provide hands-on experience to the partners for addressing the constraints in the watershed development and management on ground; and
- Learn from each other's experience in the area of watershed development and management based on the ground realities and discussions with the participating partners and farmers.

The traveling workshop is basically organized to develop new friendship bonds within the team members after visiting different countries, to work hard, and to learn new things as one travels to different watersheds in different countries. This workshop is being organized in the second year of the project and it is time to review the progress in different benchmark sites and to undertake mid-course corrective measures. You all will be visiting five on-farm and three on-station watersheds in all the three countries with different socioeconomic and natural resource endowments.

Workshop structure

Let us go over the structure which we can follow during this workshop. It is proposed to visit benchmark watersheds to take stock of the development in each watershed, to discuss with the other team members involved in the watershed research, to provide suggestions for improving the watershed, to evaluate watershed activities critically, and finally to prepare an analytical and critical report. Most importantly, whatever new things you learn and observe in other watersheds you should try to implement/introduce in your watersheds if they are relevant to your watershed.

Finally, any program or workshop is incomplete unless the expected outcome is achieved. Our targeted outputs from this workshop is a critical assessment of each benchmark watershed by you all and also a compilation of suggestions for implementation in each watershed. To achieve these outputs, a questionnaire is given to you all and you are requested to answer all the questions given in the questionnaire independently. You are advised to put your independent opinion and evaluation for each question although you can consult other participants and discuss with them. Your critical evaluations and suggestions are most important as the main objective is to learn from each other. Our on-site discussions will be most important but to consolidate all the suggestions and to do further follow-up activities it is critical that you all write down your views soon after completing the visit to each benchmark watershed.

We have full 15 days of hard work in front of us. Along with the hard work, we will make new friends in each country and see new places which will be quite interesting for all of us. I wish you a very enjoyable and fruitful Traveling Workshop-cum-Field Visit. Let us make this workshop a "Good Learning Experience" and I am confident that you all will remember this remarkable experience. So friends! Let us look forward to a rewarding and unique opportunity provided by this workshop. I wish you all the very best and happy and safe journey during the workshop. Just remember that before you leave Patancheru which is the last stop of this workshop, you will have to submit your full report for the workshop. Good luck!

S P Wani
Chair
Organizing Committee

Thanh Ha Watershed, Vietnam

Introduction

The rainfed sloping lands compose approximately one-third land area of northern Vietnam. Climate is monsoonal with hot, wet summers (April to August) and cool, cloudy, moist winters (December to February). Annual rainfall is 1300–1500 mm. Average annual temperature is 25°C, with an average maximum of 35°C in August and an average minimum of 12°C in January. Southwest monsoon occurs from May to October, bringing high temperatures and heavy rainfall. The dry season is during November to May with a period of prolonged cloudiness, high humidity, and light rain. Soils are complex and varied. The most common soil type is the red-yellow ferralitic.

Key constraints

The sloping land ecosystems have much lower carrying capacity and respond to crop intensification by rapid declines in productivity, sometimes even total collapse. Rainfall is seasonal with much of the annual total concentrated in a few short events. Inadequate distribution of rainfall during the year causes intermittent and prolonged droughts leading to crop failures or fall in crop yields and food production.

Soils are deeply weathered, poor in nutrients, and highly vulnerable to erosion when cleared of vegetative cover and are subjected to various forms of degradation. Loss of humus rich topsoil leaves behind the subsoil devoid of vital plant nutrients leading to rampant infertility and poor water-holding capacity.

Unterraced fields are highly subject to erosion with estimates of annual soil losses ranging from 150 t ha^{-1} to 350 t ha^{-1}. Micronutrients are frequently limiting. Forced by weather-related uncertainties and low incomes, farmers in sloping land ecoregions are generally resource poor and cannot invest adequately in crop husbandry.

Rice, maize, cassava, sweet potato, and potato are important components of the farming system. However, to provide greater stability to production and income, there is a need to diversify the cropping systems. There are currently no economically viable and environmentally sustainable alternatives available for sloping ecoregions of northern Vietnam. There is an urgent need for development of sustainable land and water management strategies in these ecoregions.

Benchmark watershed

The landscape watershed selected during April 1999 is located in Brigade # 7 of Thanh Ha State Farm, Kim Boi district, Hao Binh Province situated about 70 km southwest of Hanoi in Vietnam. The total land area is 1522 ha. Although 53% area is suitable for arable cropping only 28% is cropped and most of the lands have been recently brought under the plow. About 7% area is under reserve forests. The average family size is small (about 4 persons). Fifty-eight per cent of the population is in the age group of 17 to 55 years.

Activities undertaken

1. Socioeconomic surveys

Baseline socioeconomic surveys by participatory rural appraisal (PRA) and rapid rural appraisal (RRA) methods have been conducted. The emerging scenarios of rainfed farming and constraints to sustainable agriculture were identified. Some observations are:

- Pressure on the land is increasing beyond its carrying capacity.
- Monocropping is predominant. Cropping systems and natural diversity is decreasing.
- Rainfall variability and inadequacy of water availability are main constraints to the intensification of rainfed farming. Farmers are ready to invest in water development programs.
- Cost of inputs is increasing at a rate faster than prices of farm produce.
- Alternate employment opportunities are limited.
- Farmers are aware of land degradation but lack knowledge of erosion control.
- Agriculture extension is weak.

The constraints to rainfed agriculture are:

- Climatic variability particularly at crop establishment stage.
- Soil erosion is increasing over the years.
- Weeds and insects are major biotic problems.
- Drought.
- Lack of capital and non-availability of credit.
- Price fluctuations and lack of support price.

2. Quantification of natural resource base

- Databases on area, production, and productivity of major crops for the period 1985 to 1998 were collected from 7 provinces having similar agroecology.
- Databases on daily climate data for 1982 to 1997 was collected to study spatial distribution of the production constraints, analyze yield gaps, and examine the opportunities for crop intensification.

3. Watershed development

- ***Site characterization:*** Soil samples to a depth of 1.5 m from the top, middle, and lower part of the toposequence from the landscape watershed were collected and analyzed for physical, chemical, and biological properties.
- ***Topographic survey:*** Topographic survey of the landscape watershed was completed with the assistance from the National Institute for Agricultural Planning and Projection, Hanoi and topo-maps were prepared.
- ***Percolation tanks:*** Three tanks (10 × 4 × 1 m) were dug to capture runoff water and act as percolation tanks for increase of water recharge in wells.
- ***Delineation of sub-watersheds and instrumentation:*** Two micro-watersheds have been delineated. Both these are equipped with digital recorders to monitor runoff; micro-watershed also has a sediment sampler to measure soil loss.

- ***Monitoring of groundwater:*** There are twelve open wells in the watershed and water level is being monitored regularly.
- ***Soil and water conservation:***
  - Water collection trenches were dug along the contour on the upper part of the toposequence for collection and storage of runoff.
  - Waterways were demarcated, stabilized, and grassed.
  - Silt traps were dug in the waterways.
- ***Stabilization of bunds:*** About 10,000 *Gliricidia* saplings were planted on the contour bunds in order to strengthen the resistance and stability of bunds.
- ***Evaluation of exotic grass:*** New grass species are being evaluated for introduction in the waterways to serve both for erosion control and as fodder.

4. Test, validate, and evaluate improved cultivars and cropping systems under farmer conditions

- ***Improved cropping systems:*** Trials to evaluate/identify improved cropping systems with soybean, groundnut, watermelon, and mung bean as sequence crops (preceding or succeeding crops) in maize-based cropping system are continuing since autumn 1999. The new cropping systems will be compared with the traditional maize-maize cropping system for productivity and income gains and efficient usage of natural resources.
- ***Improved production practices:*** Improved production practices (improved variety, integrated nutrient, pest, and disease management, and agronomy) have been used in maize, mung bean, soybean, and groundnut since autumn 1999 cropping season. Improved production practices produced higher grain yields in soybean (1.07 t ha^{-1}) and groundnut (2.1 t ha^{-1}). High levels of inorganic fertilizers are being used in maize. Three cultural practices [$180N:90P_2O_5:90K_2O$, 10 t ha^{-1} farmyard manure (FYM), 400 kg ha^{-1} lime, and biofertilizer (practice # 1); $150N:90P_2O_5:90K_2O$, 10 t ha^{-1} FYM, 400 kg ha^{-1} lime, and biofertilizer (practice # 2); and $200–250N:80–85P_2O_5:45–50K_2O$ (farmers' practice)] were tested in maize to identify opportunities for reduction in input use. Highest grain yield was obtained with practice # 1 (5.2 t ha^{-1}) while the yields did not differ significantly with practice # 2 and farmers' practice. These results imply considerable scope for improvement in nutrient management and savings on inorganic fertilizers.
- ***Influence of toposequence:*** Effect of toposequence on grain yields of soybean, groundnut, and maize is being quantified. Higher grain yields were recorded on the middle and lower part of the toposequence while crops on top of the toposequence suffered badly due to erosion and associated soil nutrient (both applied and native) loss.
- ***Demonstration of new crops and/or improved cultivars:*** On-farm demonstrations with mung bean, soybean, groundnut, and watermelon are ongoing. Improved mung bean cultivars were evaluated as a catch crop in watermelon-maize cropping system; T 135 produced 34% higher yield (1.12 t ha^{-1}) than other cultivars.
- ***Improved varieties:*** Soybean varieties AK 06, AK 08, and DT 84 were identified as superior with yield of 1.7 to 1.8 t ha^{-1}. Bacterial wilt tolerant groundnut cultivars LO 2 and MD 7 produced higher pod yields (2 to 2.3 t ha^{-1}) than the local variety (1.0 t ha^{-1}).

- ***Use of plastic mulch:*** The effect of plastic film mulch on groundnut yields is being assessed in six groundnut cultivars (LO 2, LO 3, LO 5, V 79, MD 7, and local variety). Preliminary results indicated yield gains of 20% in winter 1999.

5. Human resource development to manage integrated watershed development projects

Training programs

In-country training course on participatory integrated watershed management

Fifteen Vietnamese scientists participated in the training course organized during 7–16 October 1999 at VASI with the objectives to:

- Teach recent concepts in integrated participatory watershed management.
- Introduce the needs of soil and water management by landscape watershed in upland agriculture in medium rainfall (800–1300 mm) tropical areas.
- Train scientists currently working in the watershed project in the design and development of efficient land and water management at watershed scale.

Training course on integrated pest management

A training course on integrated insect and disease management was organized during 18 and 19 February 2000 before the spring season plantings. On the first day, the agricultural extension officers and technicians of Thanh Ha State Farm and on the second day cooperating farmers were given on the job training on:

- Important disease and insect problems of mung bean, soybean, groundnut, and maize.
- Identification of pests and diseases.
- Seed treatment with fungicides, insecticides, and biofertilizer.
- Appropriate spraying methods.

Technology extension and public awareness

Field and farmers' days

- Two "Field Days" were organized in spring 1999 (19–20 November and 9 December 1999). Farmers, commune leaders, research managers, and extension staff from Hoa Binh Province were invited to get them familiarized with integrated watershed management technologies and demonstrate its usefulness in natural resource conservation.
- A farmers' day was conducted in the landscape watershed in April 2000. All the farmers in the Thanh Ha State Farm (consisting 7 brigades or villages) were invited to get them familiarized with different components and technologies of the integrated watershed.

Video film

The Vietnam Television crew was invited to get the watershed activities filmed for wider publicity through the media and for visitors.

Tad Fa Watershed, Thailand

Introduction

Northern and northeastern Thailand represent highland rainfed ecosystems. These areas have undulating rolling topographies. The soils of northern Thailand are heavier in texture, while those in the northeast are sandier in the surface horizons and are clayey in the sub-surface. Rainfall varies between 1100 mm and 1800 mm; it is bimodal. The rainy season sets in February–March and continues up to October. Crop yields are low (in comparison to lowlands). The farmers are relatively poor. Most of the land belongs to the state. The farmers are allocated about 4 ha of land (it is variable from province to province) on a long-term lease. Secure tenure is one of the main demands of the farmers. Farmers are not eager to invest in land development.

Most of the sloping areas in northeastern Thailand were covered with forests but due to resettlement programs that the Royal Thai Government has introduced in recent years, more and more land is being cleared-off the forests. The farmers are cultivating very steep lands. Therefore, there is an increase in land degradation due to soil erosion. Crop yields are being maintained by increasing fertilizer dosages, but now the ecosystem is getting damaged and yields are declining.

ICRISAT, in cooperation with the Royal Thai Departments of Agriculture and Land Development and the Khon Kaen University, has taken up strategic research and on-farm research to evaluate the current state of agriculture in a typical northeastern watershed. Some highlights of the on-farm research conducted during 1999 and currently under way at Tad Fa in Thailand are discussed.

On-farm research conducted in farmers' fields during 1999

1. A preliminary survey of the benchmark watershed at Tad Fa

Objective: To demarcate the watershed and enlist the area sown to different crops by farmers in 1999.

Results:

- A map of the benchmark watershed and an approximate delineation of farmers' cultivated land was prepared.
- A list was prepared including names of respondent farmers, area owned, crops cultivated, and cropping systems during 1999.

Main observations:

- Maize is the most popular crop. Farmers also grow upland rice, legumes, sunn hemp, sword bean, sunflower, and tobacco.
- Most farmers grow some fruit trees.
- There are some water reservoirs for storing runoff water. These are mainly used for recharging groundwater.

2. Physico-chemical properties of soils

Objective: To estimate the fertility, texture, and chemical properties of soils located in different parts of the toposequence.

Observations: Thirteen farmers' fields located in steep, moderate, and slightly sloping lands were sampled. The number of plots sampled were 4, 6, and 3 respectively. The soil sampling depth was 0–15 cm.

Conclusions: The soil is slightly acidic with pH 5.5 to 5.7. Organic matter is in medium range between 2.2% and 2.7%. Available phosphorus (P) is very low (range 2.2 to 2.4 ppm) especially for legumes cultivation.

Soil texture in steep slope is sandy loam while in the lower two toposequences, it is loamy sandy. Gravel content of soil in steep slope is relatively high, showing that soil erosion in cultivated area in the toposequence is high. Clay, silt, and fine sand have been lost in water erosion.

More detailed soil samples up to 110 cm soil depth have been collected for analysis by ICRISAT in April 2000. The study of the soil toposequential characteristics will be conducted by the usual laboratory analysis; a strategic research evaluation by finger-print techniques is also planned with cooperation of the Khon Kaen University.

3. Evaluation of maize yield

Almost all farm households plant hybrid maize as a cash crop. Some farmers grow maize-maize. The first crop is sown in March and harvested in May, and the second crop is sown in July to August. Early rain is normally irregular; this causes one crop failure in every 3-year cycle. Plowing method is one-way, plowing along the slope, especially for steep slopes. Here soil erosion becomes a serious problem of crop cultivation in the watershed.

Average grain yield of maize (second crop) planted by farmers in 1999 was 3.1–4.1 t ha^{-1}. Maize planted in steep slope area gave lower yields when compared to the crop cultivated on moderate to slightly moderate sloping lands.

4. Yield trials of groundnut

Objective: To compare productivity of groundnut varieties.

Groundnut is one of the economic crops of the northeastern Thailand. Some farmers planted groundnut in 1999. Only local varieties (Valencia type) were grown in about 5–10% of land. Average yield of fresh pods ranged between 2.5 and 3.7 t ha^{-1} in the first crop. Groundnut is sown in April/May and harvested in August. The variety KK 60-2 was tried as second crop and planted in August and harvested in October–November.

5. Possibility of growing soybean

Objective: To find out the possibility of growing soybean in the benchmark watershed as an alternative crop to maize.

Soybean crop grows well in the area, but the pods are seedless. This problem was encountered by a farmer who grew the crop about 2 years ago. Trials on five soybean varieties was set up to test the possibility of production of soybean in the second crop period. Soil analysis was also done to find out the cause of the problem.

Observations: Grain yields are less than 1 t ha^{-1}. Soybean normally needs at least 15 ppm of soil P for high yields, while the P in soil (15 cm depth) was estimated in the laboratory to be less than 5 ppm. Farmers themselves do not want to add fertilizer for soybean. However, CM-2 and CM-60 varieties have shown higher yield potential.

6. Productivity of upland rice

Objective: To observe the grain yield and yield components of upland rice in the sloping lands in Dong Sakarn village (Tad Fa watershed).

Observations: Upland rice is important for home consumption by poor farmers in the rural hilly area. Therefore, every farm family reserves a piece of farmland to cultivate this crop. In Tad Fa watershed, it is very common for farmers to exchange their own land with land suitable for upland rice production. About 0.5–1 ha of land is sufficient to meet household needs. The villagers plant traditional rice varieties. Lao Taek is one of the most widely used variety (by about 75% of farmers) because of its relatively high yield. It is planted in direct seeding around June–July and harvested in late October to end of November. Fertilizer application is commonly needed once in every 2 years. Average yield (dried grain) in moderate and slight sloping lands range between 3.4 and 4.0 t ha^{-1}.

7. On-farm experiments conducted to determine the productivity of rice bean in Tad Fa watershed

Objective: To evaluate the growth and yield of rice bean crop across different slopes in relay cropping with maize.

In about 40% of maize-growing area, rice bean crop is relay planted in between standing crops of maize during its flowering period in June–July with no tillage and no weeding by farmers.

Average grain yield was 0.97 to 1.36 t ha^{-1} in 1999. Steep slopes yielded less (about 25–30%) than the yields observed in slight sloping lands.

On-farm experimental plans for 2000

1. Cropping systems

1.1 Maize:
- Contour cultivation on moderately and slightly sloping lands.
- Low tillage.
- No fertilizer for some small plots in various types of sloping lands.

1.2 Maize-relay cropping with legumes:
- No tillage for second crop.
- Manual direct seeding of legumes in between maize rows.
- Legumes to be planted: rice bean and *Phaseolus vulgaris;* planting period will be during the flowering period of maize.

1.3 Sequential cropping:
- Maize-soybean.
- Maize-groundnut.

1.4 Intercropping of fruit trees with maize:
- Plant fruit trees originally in steep sloping areas of Tad Fa watershed.
- Plant vetiver grass along contour in area under fruit trees.
- Major fruit trees: longan, litchi, chesnut, and mango.

2. Environmental measurements

2.1 Soil loss assessment from water runoff:
- Built two wiers at the beginning of waterways of two contiguous watersheds. To measure water runoff and collect water for suspended matter and quality analysis.
- Automatic collectors for those two purposes were installed and already in operation.

2.2 Automatic weather station is posing problems of installation. It will be made operational soon.

Micro-watersheds at Ringnodia and College of Agriculture, Indore, Madhya Pradesh, India

Introduction

The research partnership between JNKVV and ICRISAT to work on the ADB-assisted project "Improving Management of Natural Resources for Sustainable Rainfed Agriculture" began in June 1999. The main objectives of the project are to (i) increase the productivity and sustainability of soybean-based production systems on medium and high water-holding capacity soils in the intermediate rainfall (800–1300 mm) ecoregion; and (ii) develop environment-friendly resource management practices that will conserve soil and water resources. A micro-watershed at Ringnodia village near Indore, India and another micro-watershed at the JNKVV's College of Agriculture, Indore have been identified as benchmark sites for this project. The salient features of both the micro-watersheds and progress of research and development works undertaken to date are summarized.

Ringnodia micro-watershed

Weather and topography

Ringnodia is a 390-ha micro-watershed and is a part of the National Watershed Development Project for Rainfed Areas (NWDPRA), Solsinda. It is located about 15 km from Indore city (22° 43' N and 76° 54' E, 540 m above sea level) on Indore-Ujjain highway. A major portion of about 960 mm annual rainfall is received between standard meteorological weeks (SMW) 25 and 41 (Fig. 1). The SMW between 26 and 40 are moist when rainfall is in excess of evaporative demand while the SMWs between 1 and 24, and 40 and 52 are relatively dry. Nearly 40% of the total rainfall is lost as runoff carrying precious soil and nutrients with 3–5 heavy rainstorms.

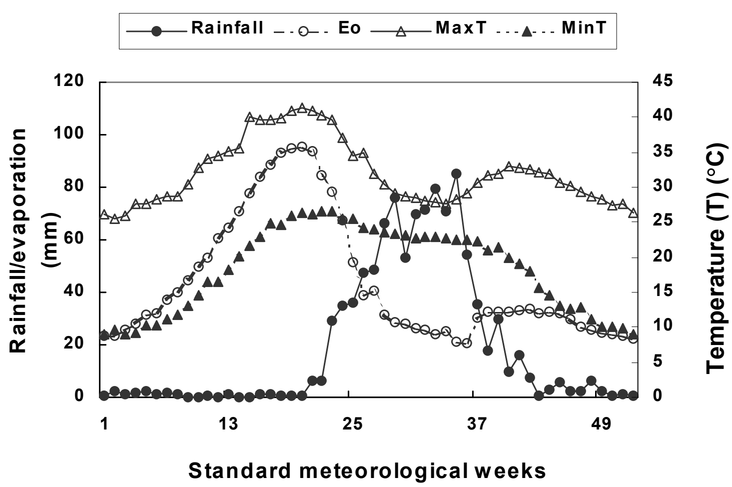

Figure 1. Long-term (1971–95) rainfall (mm), evaporation (Eo) (mm), and maximum and minimum temperatures (°C) of Indore, India.

The Ringnodia micro-watershed (RMW) has a recharge zone with >8% slope, a transition zone with 2–8% slope, and a cultivated area with <2% slope (Fig. 2). The recharge zone comprises 18.2 ha; transition zone 25.8 ha, and the area under the two ponds is 12.8 ha. It has 19 tube wells, 14 open wells, and two large ponds. Most of the tube wells of this area are generally used for irrigating crops during the postrainy season. However, the tube wells very often dry up or run with reduced discharge from February onwards. Two roads in the fields also serve as major flow pathways. The general features and problems of the micro-watershed which can be observed during a typical transect walk are given in Table 1.

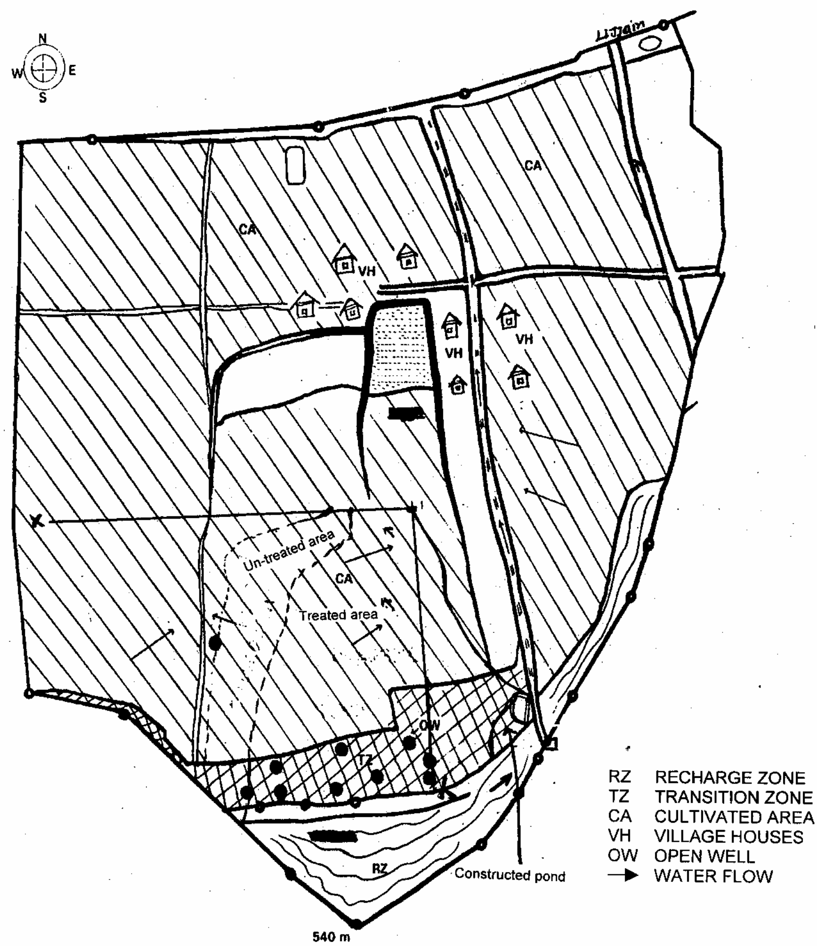

Figure 2. Slope map of Ringnodia micro-watershed, Madhya Pradesh, India.

The soils in the RMW are shallow to deep black with variable depth. They occur on bare hill slopes to flat topography. The cultivated soils are mostly clay loam in texture with high moisture retention capacity, normal to somewhat alkaline reaction (soil pH 6.5–8.5), and low electrical conductivity (<1.00 dS m^{-1} at 25°C). Most soils are low to medium in basic soil fertility with respect to available nitrogen (N) and P and high in available potassium (K).

Table 1. Summary of the general observations of transect walk in Ringnodia micro-watershed, Madhya Pradesh, India.

Item	First transect walk from South to North	Second transect walk from North to South	Third transect walk from South to North
Soil types	Black soil, clay, sandy	Black soil, sandy loam with stones, fine and gravel	Sandy loam, black soil, fine and gravel.
Land use	Fields, farm land	Village, agricultural fields, kitchen gardens	Farm land, grazing
Topography	Hilly, slopy, normal	Normal, slopy, hilly	Hilly, slopy, normal
Crops	Soybean, maize	Soybean, rosha grass, maize, sorghum, okra, sponge gourd, chili	Soybean, maize, sorghum, marigold
Animals	Cow, buffalo, poultry	Cow, buffalo, goat, poultry	Goat, cow, buffalo
Trees	Babool, mango, neem	*Acacia*, guava, *Ziziphus*, mango	*Acacia*, guava, eucalyptus
Irrigation	Tube wells and ponds	Tube wells and ponds	Tube wells and ponds
Problems	• Soil erosion. • Low germination in soybean.	• Water stagnation. • Poor drainage. • Poor roads. • Soil runoff. • Low availability of pasture.	• Soil erosion. • No water harvesting during rain.
Opportunities	• Soil is suitable for cultivation of crops such as soybean, cotton, and maize. • Potential for social forestry.	• Better breeds of animals can be a source of income. • Potential for fruit and vegetable growing. • Pond for water harvesting during rainy season.	• Potential for water harvesting during the rainy season in the recharge zone. • A few fields under marigold indicate the potential for floriculture.

Land use pattern/cropping pattern

In the rainy season (June to October) soybean covers more than 95% of the cultivated land irrespective of soil, slope, depth, and capability, the remaining area being under fodder and vegetables. Soybean is sometimes grown as mixed crop with maize. A limited cultivation of fodder sorghum is also not uncommon on some lands. During the postrainy season, the winter crops grown are wheat, chickpea, linseed, and lentil in some pockets. In the postrainy season, wheat is grown in about 75% area, chickpea in about 15% area, and other winter crops in about 10% area. The other crops include berseem for fodder, potato, onion, and garlic.

Soil and water conservation measures undertaken at Ringnodia

- Water storage structures in three segments have been constructed as detailed in Table 2. Effect of these storage structures on groundwater was being monitored regularly in nine open wells (Fig. 3), which currently dry up after February.
- Water diversion bunds measuring 275 m length were constructed.
- Topographic survey of 60 ha area in the RMW was completed. This will help in designing land and water management options for the safe disposal of water, and reduce runoff and soil erosion.
- Vegetative barriers were planted to stabilize bunds.
- Participatory on-farm testing of soybean on narrow beds using Directorate of Wheat Research (DWR) planter was undertaken during the 2000 rainy season. The DWR planter does ridge making, fertilizer application, and sowing simultaneously, thus saving considerable time, which is critical to work on black soils. There was considerable initial reluctance among farmers as they suspected that this would hamper interculture operations as well as reduce soybean yields due to fewer rows being planted per unit area. These impressions will be hopefully corrected as establishment and growth of soybean on broad ridges (75 cm) have indicated that the machine is excellent and precise planting using this machine has rather facilitated interculture operations.
- Farmers showed reluctance to implement broad-bed and furrow (BBF) configuration of land for they felt this is an extra-operation after land has been prepared. They felt it would reduce soybean population. A few farmers, who prepared BBF in their fields, dismantled them subsequently.
- Farmers have also constructed channels for the safe disposal of water.
- Several loose boulder structures to reduce velocity of runoff water have been constructed.
- Runoff and sediment recorders have been installed for measuring water and soil loss.

Crop-related activities undertaken

- The performance of medium-duration pigeonpea in intercropping systems with soybean and as pure crop on shallow and medium soils was tested. Even though pigeonpea/ soybean intercrop proved more remunerative than soybean alone (Table 3), farmers were little reluctant to practice it because medium-duration pigeonpea reduced the possibility of a postrainy season crop. Further, stumps of stubbles left after the harvest of pigeonpea seem to damage tractor tyres. So in the 2000 rainy season, no farmer came forward to grow medium-duration pigeonpea as a pure crop or intercrop with soybean.
- Introduction of extra-short-duration pigeonpea (ICPL 88039) is being taken in the 2000 rainy season. There are more than 30 on-farm trials within the RMW and a similar number outside the RMW. This was the most preferred option by farmers, but not many farmers grew it as an intercrop with soybean as they wanted to have first hand experience that it could mature along or soon after soybean.
- Integrated pest management was practiced through combined use of chemicals and botanicals.
- A four-seeded soybean variety (JS 90–41) was tested along with the prevalent soybean variety JS 335.

- Conjunctive use of reduced levels of N and P fertilizer and biofertilizers was evaluated. Soil test based recommendation proved superior to blanket recommendation or farmer practice in 1999 (Table 4). *Rhizobium* inoculation also improved productivity even at half the rate of recommended fertilizer application.

Table 2. Salient features of water storage structures at Ringnodia micro-watershed, Madhya Pradesh, India.

Feature	Segment 1	Segment 2	Segment 3
Area contributing to pond	4.5 ha	3.5 ha	1.5 ha
Type	Earthen bund	Earthen bund	Earthen bund
Shape	Semi-circular	Trapezoidal	Trapezoidal
Length of bund	110 m	110 m	65 m
Top width of bund	3.2 m	3.2 m	3.2 m
Storage capacity (maximum)	110 ha-cm	100 ha-cm	48 ha-cm
Excavation earthwork	1620 m^3	1200 m^3	460 m^3

Table 3. Productivity of soybean and pigeonpea in monocropping and intercropping systems in farmers' fields at Ringnodia micro-watershed, Madhya Pradesh, India.

Treatment	Yield (kg ha^{-1}) at different locations			Mean	LER[1]	Gross returns (Rs ha^{-1})
	1	2	3			
Pure soybean	960	780	765	835	1.0	6680
Soybean/ Pigeonpea	782 + 940	636 + 826	652 + 786	690 + 851	1.7	18285
Pure pigeonpea	1330	1140	-	1239	1.0	18585

1. LER = land equivalent ratio.

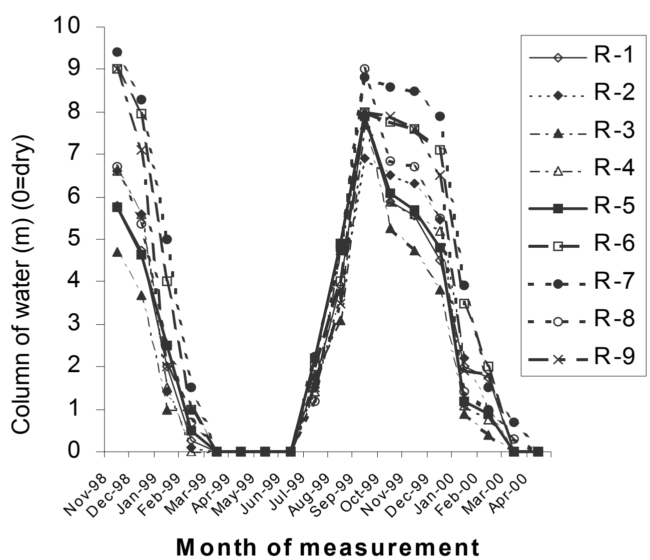

Figure 3. Water table fluctuations in nine wells at Ringnodia micro-watershed, Madhya Pradesh, India.

Table 4. Yield of soybean (JS 335) and chickpea (Ujjain 21) varieties as influenced by different treatments in Ringnodia micro-watershed, Madhya Pradesh, India.

Treatment	Yield (kg ha^{-1}) at different locations				Average	Increase over farmers' practice (%)
	1	2	3	4		
Soybean						
Farmer's practice	624	718	685	656	656	
Soil test based recommendation	888	832	794	812	832	27
Chickpea						
Farmer's practice	438	516	408	442	451	
Soil test based recommendation	592	658	565	578	598	33
Farmers' practice	448	402	394	412	414	
Half of recommended dose of fertilizer + *Rhizobium*	554	504	432	492	496	20

Other activities

- Formulation of self-help groups in RMW was completed.
- Creation of mass awareness about soil and water conservation, balanced nutrition to milch animals, efficient land and rainwater utilization was undertaken by organizing village meetings.
- Planting of fruit trees, floriculture, and *Gliricidia* was undertaken.
- Characterization of socioeconomic and natural resources, and identification of constraints to higher productivity were carried out using PRA tool. Six Agricultural Research Services trainees of the Indian Council of Agricultural Research (ICAR) also facilitated this exercise. The salient findings of the PRA suggests:
  - Even though the village has <40% literacy, considerable adoption of modern agricultural and dairy technologies was observed.
  - Water scarcity after the rainy season is quite acute. Rainwater harvesting during the rainy season increased crop productivity in the village and availability of drinking water.
  - Soybean is the main crop during the rainy season, but due to buildup of insect pests and low prices, farmers are also interested in growing other crops.
  - Use of less water requiring crops such as chickpea is likely to improve farm productivity in the postrainy season.
  - Due to proximity to the city of Indore, there is considerable scope for adopting integrated crop and dairying technologies for improving the economic conditions of farmers.

JNKVV College of Agriculture micro-watershed

A 2-ha micro-watershed was developed to test efficacy of best bet options for rainwater harvesting and conservation of soil and nutrients. Land treatments such as BBF and flat beds were compared since 1999 rainy season in conjunction with water use efficient cropping systems such as soybean/pigeonpea, and soybean followed by chickpea, wheat, and linseed during postrainy season. Overall productivity of any crop and cropping system was similar on BBF and on flat beds. Intercropping of soybean and pigeonpea could sustain adverse weather conditions and utilize residual moisture effectively and thus produce largest economic returns (Table 5).

Installation of equipment for recording runoff and soil loss data from the micro-watershed has been completed. Detailed baseline productivity survey has been completed. The average productivity over four seasons from 1995 to 1998 of different soybean cultivars, which is the main crop during the rainy season, was only 1.16 t ha^{-1} with a range of 0.7–3.5 t ha^{-1}

Table 5. Productivity of different crops and cropping systems at on-station watershed at JNKVV College of Agriculture, Indore, Madhya Pradesh, India.

Cropping system	Yield (kg ha^{-1})			Monetary return (Rs ha^{-1})
	Soybean	Component crops	Total system	
Broad-bed and furrow				
Soybean-chickpea	980	532	1512	12670
Soybean-linseed	950	541	1491	14980
Soybean/pigeonpea	632	1068	1700	20780
Soybean-wheat	850	894	1744	13080
Flat seedbed				
Soybean-chickpea	888	465	1353	11320
Soybean-linseed	1068	562	1630	16420
Soybean/pigeonpea	603	1034	1637	20030
Soybean-wheat	905	1035	1950	14550
SE ±	67.0	74.1		

Research team

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Lalatora Watershed, Madhya Pradesh, India

The project is being undertaken by BAIF[1] under the aegis of ICRISAT, Patancheru, Andhra Pradesh, India. It was initiated during 1998.

Location

ICRISAT/BAIF chose Lalatora village (of the Lateri II Watershed) of Vidisha district in Madhya Pradesh state of India after careful deliberation. Lalatora village is located in an extensive watershed totaling about 10525 ha, lying between 28° 8' 3" and 24° 16' N, 77° 20' 45" and 77° 30' 15" E at a height of 415 m above mean sea level. This watershed is being managed by BAIF. This region has been receiving over 1300 mm of rainfall over the last decade (Table 6).

It is pertinent to note that Madhya Pradesh is the largest soybean-growing state in India where more than 5 million ha produce about 4 million t of soybean, which amply supports the project objective of studying sustainability of agriculture in the rainfed tropics. The project aims to develop and apply environment-friendly techniques to increase the productivity in these areas of medium to high water-holding capacity soils.

Constraints to crop production

- High runoff and soil erosion
- Severe waterlogging
- Degraded soils
- Low rainwater use efficiency (about 30–50%)
- Groundwater depletion
- Low cropping intensity
- Resource-poor farmers'

Objectives

- Conduct investigations to select the appropriate components for sustainable land, water, and crop management practices compatible with existing and/or viable systems.
- Strengthen the capability of watershed level farmers' institutions to develop their own technologies and to adapt technologies generated by ICRISAT and consortium institutions by partnership approach.

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1. BAIF reaching out to the rural people:
BAIF Development Research Foundation, popularly known as BAIF, is a voluntary organization. BAIF has been revolutionizing the concept of community development for over the past three decades taking into consideration, the rich indigenous knowledge of the rural community. Drawing inspiration from the pragmatic approach and development philosophy of its founder, late Dr Manibhai Desai, a disciple of Mahatma Gandhi and a Ramon Magsaysay awardee, this professionally managed organization is implementing a multidisciplinary program in rural development through cattle development, tree-based farming systems, watershed management, community health, and women empowerment. BAIF is providing valuable services to more than a million rural families in about 8,000 villages through an extensive network spread over seven states in India.

- Enhance capability building of farmers' groups by providing training personnel and provision of other needed resources.
- Facilitate dissemination and sharing of information by conducting co-sponsored seminars, conferences, and workshops as necessary.

Table 6. Some baseline data on the watershed allotted to BAIF in Madhya Pradesh, India.

A. Coverage [obtained from the District Rural Development Agency (DRDA)]

Micro-watershed	Area[1] (ha)	Villages in micro-watershed
Haiderpur	700	Haiderpur, Mina Umaria, Banarsi, Salra
Haripur	825	Haripur, Vijnipur, Kilankhedi
Nisso Barri	875	Nisso Barri, Dondkheda, Motipur
Jaoti	575	Jaoti, Kundankhedi
Kolapur	750	Kolapur, Shahpur
Golakheda	750	Golakheda, Dharnawada
Chopna	725	Chopna, Marauta
Bapcha	725	Bapcha, Ramnagar
Lalatora	725	Lalatora, Mehmoodgunj
Anandpur	625	Anandpur, Barkheda
Khairkhedi	625	Khairkhedi, Musrakheda
Kundalpur	650	Kundalpur, Bhanpur
Okhlikheda	500	Okhlikheda
Fazalpur	400	Fazalpur
Bandipur	475	Bandipur, Badi Sumer
Rahimpur	300	Rahimpur
Kuraikheda	300	Kuraikheda, Visrampur
Total	10525[1]	

1. This area is an approximation.

B. Rainfall in mm [collected from the India Meteorological Department (IMD) raingauge at block level][2]

Month	1989	1990	1991	1992	1993	1994	1995	1996
Jan	28	264	71	8	94	244	26	478
Jul	276	333	346	281	278	444	238	630
Aug	407	377	388	650	288	333	280	28
Sep	92	339	19	133	564	166	128	60
Oct	-	33	-	-	-	-	-	-
Nov	-	-	-	-	-	-	-	-
Dec	-	9	-	-	-	-	-	-
Total	803	1355	824	1072	1224	1137	672	1136

2. Data for 1997–2000 is being collated.

The strategy

In developing and managing this watershed, we have been following participatory planning, development, and assessment approach as given below:

- Linking strategic research with watershed development to enhance effectiveness of community watersheds.
- Multi-disciplinary and multi-institutional consortium approach for technical back stopping of the watershed based developments projects.
- Micro-watersheds are used as up-front demonstrations managed by farmers with technical backstopping.
- On-farm strategic research conducted in partnership with farmers and BAIF.

The farmers of the watershed have been actively participating in need assessment, planning, implementing, monitoring, and evaluation work.

Strategic on-farm research

- Land and water management systems
- Groundwater studies
- Fertility and nutrient management
- Integrated pest management
- Improved crop varieties

Action plan

The following studies are proposed to be carried out in this region:

- Baseline study through a study of the crop practices prior to initiation of this project.
- Baseline study through a techno-economic survey.
- Topographic and complete soil survey and profiling of the project region.
- Crop-based trials in rainy season and postrainy season with the provision of vital inputs such as improved seed, seed treatment material, and advice of best bet package of practices.
- Evaluation of land surface configurations (BBF and flat).
- Hydrological studies at watershed level.
- Fertility and nutrient studies.
- Construction of check dams, farm ponds, percolation tanks, gully plugging, and stone bunding (these have been constructed).
- Microclimatic conditions of the region through an automatic weather station.

Tactics

ICRISAT has an annual work plan which translates the components of the action plan into manageable annual parts.

Baseline study through a study of the crop practices prior to initiation of this project

Before the project was initiated, all the agriculture operations relating to a crop and crop season were recorded through village meetings. This gave an insight into the level of advancement of the agricultural practices in the region.

Baseline study through a techno-economic survey

This field level study has been successfully completed in the selected villages and creation of the database remains after which firm conclusions may be drawn. BAIF has also added a questionnaire on the landless labor who are among the groups of people affected by cropping practices.

Geo-hydrology of the area through a study of the area on a watershed basis using soil and water runoff recorders: Treating the entire selected project area as a watershed has been facilitated with the presence of major natural drains in the area which help carry excess water into the seasonal river Kaandai. Water runoff recorders presently help record the amount of water that is being wasted. It is proposed to install a sediment sampler too since the problem of vandalism has been identified and controlled.

A complete soil survey and profiling of the project region

This very basic study has been done; both physical on the ground as well as satellite studies have been carried out in the project region keeping in view the virgin unexploited state of the soils. The soil tests reveal that the soils are lacking in sulfur (S) and boron (B) for which micronutrient studies have been designed. Field experiments are being carried out in soybean and results are awaited. However, as an interim observation the farmers are of the opinion that addition of both the nutrients has led to more vigorous growth of the crop plants.

Crop-based trials were conducted in rainy season and postrainy season with the provision of vital inputs such as improved seed, seed treatment material, and advice of best bet package of practices (Tables 7 and 8). Also N-fixing ability of soybean was compared with that of maize.

ICRISAT being a crop research institute, field trials in farmers' fields assume great significance towards preventing the "ivory tower" approach to development planning. With a view to preventing the 'dependency syndrome' it has been decided to supply all inputs at a subsidized rate but not free.

Table 7. Crop yields in trials in farmers' fields in Lalatora watershed, Madhya Pradesh, India.

No. of farmers	Area covered (ha)	Average yield (kg ha^{-1})	Average yield with traditional practices (kg ha^{-1})	Interventions
Soybean (JS 335) in rainy season 1999				
27	40.50	1275	950	Supply of seed, seed treatment, fertilizer recommendation, and other related information
Chickpea (ICCV 2, ICCV 10, and ICCV 37) in postrainy season 1999				
44	11.25	957–1471	923[1]	Improved seed, seed treatment, reduced tillage, and other related information

1. Productivity in the neighboring region.

Table 8. Trials conducted with soybean variety JS 335 during rainy season 2000, Lalatora watershed, Madhya Pradesh, India.

Trial	No. of farmers	Area covered (ha)	Interventions
Broad-bed and furrow (BBF)	8	6	Layout of BBF, topographic survey, and BBF maker.
Micronutrients (boron and sulfur)	12	6	Micronutrients in the form of borax (@ 10 kg ha^{-1}) and gypsum (@ 200 kg ha^{-1}).
Nitrogen (N)	45	45	Seed treatment. Maize markers to study the quantity of N fixed by the soybean crop.

Evaluation of broad-bed and furrow (BBF) system of cultivation

Since the black soils at this location are prone to waterlogging, BBF technology is being tested. The initial resistance has received a shot in the arm with the BBF exhibiting signs of low and slow germination due to apparently poor sowing practices. The situation will be remedied by offering adequate training to the farmers for the next season.

Evaluation of zero tillage for chickpea

In a rainfed sequential cropping where irrigation facilities are not available, soil moisture plays an important role in establishment of postrainy season crop. Farmers generally prepare the land after harvesting rainy season soybean for sowing chickpea. Based on the results from the on-farm watershed, it was observed that direct seeding chickpea after harvesting soybean not only helped in better crop establishment, but also reduced the incidence of collar rot (*Sclerotium rolfsii*) in chickpea and increased chickpea grain yields. We suggested to the farmers to evaluate the practice of zero tillage for postrainy season chickpea crop. In the postrainy season zero tillage planting of chickpea (planting chickpea soon after harvesting soybean without plowing) was evaluated on a 4-ha farm by one farmer. The zero tillage and normal tillage practice plots received 37.5 kg di-ammonium phosphate (DAP) ha^{-1}. Seeds were inoculated with *Rhizobium* and phosphate solubilizing bacteria. In zero tillage plots yield of chickpea was 1423 kg ha^{-1} (27% higher) as compared to 1125 kg ha^{-1} from normal tillage plots.

Microclimatic conditions of the region through an automatic weather station

Continuous monitoring of prime weather indicators (such as wind speed and direction, minimum and maximum temperatures, solar radiation, rainfall, and soil temperature at different depths) helps in assessing the suitability of various cropping patterns before they are recommended in the region.

Future actions

It is proposed to monitor around 60 ha of chickpea crop in the postrainy season. About 3000 kg of improved seed has been procured from the farmers for distribution in the coming crop season.

Postrainy season 2000 (proposed actions)

- Effectiveness of BBF system in postrainy season will be studied.
- The efficiency of application of supplemental irrigation in BBF system for wheat crop will be studied in different farmers' fields.
- Reduced tillage system will be studied at more locations.

It is proposed to monitor the crop growth and development as well as harvesting in about 100 ha for three improved varieties of chickpea for which 3 t of seed produced from the postrainy season 1999 crop has been purchased and stored for subsidized sale to farmers. It is interesting to note that these three varieties are ICCV 2, ICCV 10, and ICCV 37.

Another interesting fallout of this project has been the enthusiasm shown by progressive farmers from the neighboring areas (especially the district of Rajgarh) whereby islanding of development works is avoided. It is the intention of this project to improve the family income of the farmer through advances in crop science.

Watershed at Indian Institute of Soil Science, Bhopal, Madhya Pradesh, India

Establishment of on-station watershed for improved SWNM at IISS, Bhopal

The Indian Institute of Soil Science (IISS), Nabi Bagh, Bhopal is located in the heartland of soybean production area (23° 18' to 23° 20' N and 77° 24' to 77° 25' E and altitude 490 m) of Madhya Pradesh, India. The average annual rainfall is 1130 mm and ranges from a minimum of 690 mm in 1992 to a maximum of 1520 mm in 1982. The annual rainfall distribution is almost symmetrical (skewness = 0.023) about the mean (1129.7) and platykurtic (kurtosis = –1.116). The rainfall is mainly received (89.3%) during June to October. The region is endowed with excess rainwater which can be stored in the reservoir in the watershed for supplemental irrigations. The reservoir water provides additional advantage of recharging the groundwater.

A reservoir of 2.5 ha-m capacity with 2 m depth has been constructed in IISS watershed. About 1.5 ha area is developed for BBF and flat on grade (FOG) land treatments. These field plots are having H flumes equipped with automatic runoff recorders and sediment samplers for assessing runoff and sediment. Weather data are collected at automatic weather station.

About 1 ha area had a field experiment on soybean-based cropping systems. *Gliricidia* leaf manure farm has been developed for providing *Gliricidia* leaves to some of the treatments in the land treatment experiment. *Gliricidia* plants have also been planted on the bunds.

Strategic soil water nutrient management in the watershed

Experiment 1: Effect of irrigation and nutrient management on soybean-wheat cultivated under varying land treatment

This eco-region provides productive environment for soybean-based production systems, but yields of crops are poor. Safe drainage of rainwater from crop fields and its storage in water harvesting pond and use of integrated SWNM approach enhance and sustain the soybean-based cropping systems. With this hypothesis a field experiment is being conducted with the following treatments:

1. *Land treatment*
   (i) Broad-bed and furrow (BBF)
   (ii) Flat on grade (FOG)

2. *Irrigation treatment*
   Soybean: Rainfed
   Wheat: (i) Pre-sowing irrigation, one irrigation at crown root initiation (CRI) and flowering stage
   (ii) Pre-sowing irrigation, one irrigation at CRI, maximum tillering and flowering stage

3. *Nutrient treatment*
   - (i) N_0P (N_0 = 0 kg N ha^{-1})
   - (ii) NP_0 (P_0 = 0 kg P_2O_5 ha^{-1})
   - (iii) NP (N = 30 kg N ha^{-1}; and P = 60 kg P_2O_5 ha^{-1})
   - (iv) N_{50i} +N_{50g} (N_{50i} = 50% of N through fertilizer; and N_{50g} = 50% of N through *Gliricidia*)
   - (v) N_{50i} +N_{50f} (N_{50f} = 50% of N through FYM)
   - (vi) N_{50f} +N_{50g}

In this field experiment some treatments are selected for assessing the atmospheric N fixation by soybean crop using ^{15}N isotope.

Experiment 2: Evaluation of soybean-based cropping systems under different irrigation and nutrient management schedules in the watershed

A field experiment consisting of the following treatments with three replications is in progress:

1. *Production system*
   - (i) Soybean-chickpea
   - (ii) Soybean-linseed
   - (iii) Soybean-wheat
   - (iv) Soybean + *Gliricidia*-wheat + *Gliricidia*
2. *Irrigation*
   Soybean: Rainfed
   Winter crops:
   - (i) Pre-sowing
   - (ii) Pre-sowing + one irrigation at the most critical stage of crops
3. *Nutrient management*
   Soybean: FYM @ 4 t ha^{-1} + recommended dose of NPK
   Winter crops:
   - (i) No fertilizer
   - (ii) 50% of recommended dose of NPK
   - (iii) 100% of recommended dose of NPK

The recommended doses of N, P_2O_5, and K_2O applied to crops are given below:

Crop	Recommended dose (kg ha^{-1})		
	N	P_2O_5	K_2O
Soybean cv JS 335	30	60	30
Wheat cv Sujata	120	60	40
Chickpea cv Ujjain 21	20	40	20
Linseed cv RS 52	60	30	30

The results of winter season (1999–2000) experiment are summarized below:

Wheat and wheat + Gliricidia: The maximum grain yield was with two irrigations and recommended dose ($I_2 \times N_{120}P_{60}K_{40}$) followed by $I_2 \times N_{60}P_{30}K_{20}$. It was further found that the difference in grain yield between $I_2 \times N_{60}P_{30}K_{20}$ and $I_1 \times N_{120}P_{60}K_{40}$ was not significant. The performance of wheat in sole wheat crop and in wheat + *Gliricidia* system was similar.

Chickpea: The main effect of irrigation and the interaction effect of irrigation and fertilizer on grain yields of chickpea were not significant. Highest grain yield of 1871.9 kg ha^{-1} was recorded under two irrigations and 100% NPK dose ($I_2 \times N_{10}P_{20}K_{10}$).

Linseed: The seed yield of linseed increased significantly with increase in fertilizer dose. Two irrigations and 50% of NPK application ($I_2 \times N_{20}P_{40}K_{20}$) produced the seed yield (870 kg ha^{-1}) that was on a par with that obtained (890 kg ha^{-1}) with one irrigation and 100% NPK application ($I_1 \times N_{20}P_{40}K_{20}$).

Experiment 3. Impact of waterlogging on growth and yield of soybean on a Vertisol

Rainfall during rainy season frequently causes waterlogging causing an anaerobic condition in Vertisols of this region. The poor drainage causes congestion and reduces soybean yield. For quantifying the effects of waterlogging during different crop growth stages on soil and plant processes and yield of soybean a field study is being carried out with the following treatments:

1. *Waterlogging during vegetative stage*
   - (i) Waterlogging for 2 days at 10–15 days after sowing (DAS)
   - (ii) Waterlogging for 4 days at 10–15 DAS
   - (iii) Waterlogging for 6 days at 10–15 DAS
   - (iv) Three cycles of waterlogging (3 days waterlogging followed by 6 days recovery period per cycle) starting at 10–15 DAS.

2. *Waterlogging during reproductive stage* (R)
   - (i) Waterlogging for 2 days at R1
   - (ii) Waterlogging for 4 days at R1
   - (iii) Waterlogging for 6 days at R1
   - (iv) Three cycles of waterlogging (3 days waterlogging followed by 6 days recovery period per cycle) starting at R1

3. *Waterlogging during both vegetative and reproductive growth stages*
   - (i) Waterlogging for 2 days at 10–15 DAS and at R1
   - (ii) Waterlogging for 4 days at 10–15 DAS and at R1
   - (iii) Waterlogging for 6 days at 10–15 DAS and at R1
   - (iv) Three cycles of waterlogging (3 days waterlogging followed by 6 days recovery period per cycle) starting at 10–15 DAS and at R1

4. *No waterlogging*

Integrated Management of BW7 Watershed in Vertic Inceptisols at ICRISAT, Patancheru, India

Background

Vertic Inceptisols in association with Vertisols occur in a toposequence and they occupy about 60 million ha in India. These soils have similar physical and chemical properties as the Vertisols except that they are more shallow (depth of the black soil material) and they are lighter in texture and occur in slopes not exceeding 5%. The productivity in these soils is threatened because of severe depletion/loss of soil, nutrients, and beneficial organisms. The watershed approach is taken up for these soils to manage the natural resources, particularly rainfall, to control soil erosion, and to improve the rainfall use efficiency.

Introduction

This study is conducted at an operational scale black watershed (BW7) at ICRISAT, Patancheru (17° 32' N and 78° 16' E and 540 m elevation), India. On the basis of topographical survey, a small watershed of 15 ha was designed and developed. The main purpose of our experimental watershed is to link strategic research in NRM with developmental research to increase productivity of rainfed agriculture, and to maintain the natural resource base. Of the 72 million ha black soils in India, 60 million ha are Vertic Inceptisols which are prone to severe land degradation.

The major constraints to sustain productivity of soybean-based systems in these soils are:

- Inappropriate land and water management practices.
- High runoff and soil erosion.
- Depletion of soil nutrients, organic matter, and soil biota.
- Waterlogging.
- Cropping intensity on Vertic Inceptisols.

Objectives

The major objectives are to:

- Evaluate soybean-based cropping systems based on the agroecological potential of the region.
- Increase systems productivity through adoption of improved soil, water, nutrient and pest management technologies.
- Test and validate the crop simulation for growth, yield, and water balance for the Vertic Inceptisol environment.

The strategy

In this project, we plan to develop and evaluate integrated SWNM strategies for sustainable crop production in partnership with NARS. All our research is being conducted in agricultural watershed as "loci". Multidisciplinary teams explore all scientific aspects of soybean production; the target here is maximum rain water use and minimal land degradation. This watershed is being used as a field laboratory to establish soil, water, and nutrient balances and crop production.

Partners

- Michigan State University, USA.
- Indian Institute of Soil Science (IISS), Bhopal, India.
- Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad, India.
- University of Georgia, USA.

Watershed development

The soil here, as mentioned above is a Vertic Inceptisol, which is classified as a member of the fine, montomorillotic isohyperthermic family of paralithic Vertic Ustopepts, of the natural variability in soil depth. The whole watershed was divided into shallow (<50 cm soil depth) and medium deep (≥50 cm soil depth) blocks. Each block was further divided into two parts with landform treatments (BBF and flat landform systems). The whole watershed thus consists of four hydrological units with two soil depths and two landform treatments; BBF landform had *Gliricidia* plantings on contour bunds and flat landforms with contour sowing.

Experimental details

- The soybean-chickpea cropping system was studied from 1995 and the soybean-pigeonpea cropping system was studied from 1996.
- Before the beginning of the rainy season, the plots were plowed and prepared into BBF and flat landforms.
- Single super phosphate was broadcasted and incorporated into the soil to provide 20 kg P ha^{-1}.
- Soybean (cv PK 472) seeds were treated with *Bradyrhizobium japonicum* and were sown.
- In BBF landforms, 4 rows of soybean with 33.3 cm row spacing were planted.
- Plant population in both the landforms were maintained at 30 plants m^{-2}.
- In the postrainy season, chickpea seeds which were also treated with *Bradyrhizobium* species were sown.
- In both the systems row spacing adopted for chickpea crop was 50 cm and population was 30 plants m^{-2}.
- Farmyard manure and *Gliricidia* loppings were applied to the crop to the BBF landform treatments.
- Appropriate pest and disease control measures were taken.
- The same specifications were followed for soybean-pigeonpea cropping system from 1996.

Results

Runoff and soil erosion

In both the shallow and medium-deep soils, the total runoff, peak runoff rates, and soil erosion were lower on the BBF landform than on the flat landform. In 1995, the BBF landform had only

168 mm of runoff recorded against 196 mm in flat landforms. In 1998 also, the BBF landforms had only 225 mm of runoff , whereas in flat landforms it was about 286 mm.

Water budgeting

Total rainfall received during the season up to physiological maturity of soybean was 640 mm. The total runoff from the BBF landform was less than that from the flat system up to physiological maturity. The total runoff during the season ranged from 11.6% to 14.0% of rainfall across treatments, whereas the drainage beyond 95 cm depth ranged from 22.8% to 33.0% (Table 9). Deep drainage was more in the shallow soil (28.1 to 33.0%) than in the medium-deep soil (22.8 to 24.0%). Thus, the total water loss across the treatments during the season was 35.8–44.6%. Water used by the crop (evapotranspiration) across treatments ranged from 59.1% to 61.7%.

Table 9. Effect of land surface treatments on water balance components of soybean in the Vertic Inceptisol watershed at ICRISAT, Patancheru, India.

Water balance component	Land treatment[1]			
	Flat shallow (mm)	BBF shallow (mm)	Flat medium deep (mm)	BBF medium deep (mm)
Runoff (R)	87 (13.7)	74 (11.6)	89 (14.0)	75.7 (11.8)
Drainage (D)	180 (28.1)	211 (33.0)	146 (22.8)	155.6 (24.0)
Soil evaporation (Es)	189 (29.5)	189 (29.6)	185 (28.8)	184 (28.7)
Transpiration (Ep)	190 (29.6)	190 (29.7)	211 (32.9)	211 (33.0)
Soil water change	–4.7	–23.7	+11.0	+15.0
% Water loss (R+D)	41.8	44.6	36.8	35.8
% Water use (Es+Ep)	59.1	59.3	61.7	61.7

1. Figures in parenthesis are the water balance components as percentage of rainfall.

Productivity and sustainability

- The total systems biomass productivity over all the years under study was more in medium-deep soils than in the shallow soils (5.9 t ha^{-1} vs 5.2 t ha^{-1} in soybean-chickpea system and 7.4 t ha^{-1} vs 6.9 t ha^{-1} in soybean-pigeonpea system).
- BBF landform with improved management practices produced more yields than the flat landforms in 1996 in both the cropping systems (6.7 t ha^{-1} vs 6.0 t ha^{-1}).
- Soybean-pigeonpea cropping system recorded more total systems productivity in terms of total dry matter over soybean-chickpea cropping system (7.1 t ha^{-1} vs 5.5 t ha^{-1}).
- Total systems productivity in terms of grain yields was more in soybean-chickpea system than in soybean-pigeonpea system over all the years (2.6 t ha^{-1} vs 2.1 t ha^{-1}).

- The yields were much higher than the soybean yields (<1.0t ha^{-1}) reported from the target region of Madhya Pradesh, India.

Nutrient budgeting

Integrated nutrient management followed in the improved system (sowing on BBF and *Gliricidia* on the bunds) resulted in a balanced budget of nutrients for the cropping system.

Soybean-pigeonpea cropping system

- *Gliricidia* loppings provided 25 kg N ha^{-1} yr^{-1} and FYM which is incorporated in the soil provided 16.3 kg N ha^{-1} yr^{-1}.
- Soybean, pigeonpea, and chickpea could get 75%, 89%, and 42% respectively of their N requirement through biological N fixation (BNF).
- Conventional system, i.e., sowing on flat landform relying only on BNF, resulted in negative N balance, i.e., depletion of soil N of about 200 kg ha^{-1} in the first four years (55 kg N ha^{-1} yr^{-1}).
- Nutrient uptake by the plants growing on BBF landform was more.
- BBF landform had more positive P balance (+14) and less negative K balance (–40) compared to flat landform with less positive P balance (+10) and more negative K balance (–60).

Soybean-chickpea cropping system

- On the whole, over four years there was 60 kg ha^{-1} depletion of N from the landforms than the improved landform.
- Transfer of nutrients within the farming systems is unbalanced and negative in flat landforms as there is more loss of nutrients through runoff and erosion.

Soil chemical and biological properties

- In both deep and shallow soils with BBF landform, there is negative net N mineralization which clearly shows immobilization due to available organic matter and in turn availability of more nutrients to the crops.
- Soil respiration was found to be more in the BBF landform than the flat landform.
- Microbial biomass carbon (C), N, and mineral N were found to be more in medium-deep soils than in shallow soils.

Simulation modeling

- CROPGRO-Soybean model predicted reasonably the temporal changes in leaf area index (LAI), biomass, and grain yield. This model is used to develop yield-evapotranspiration (ET) relationship and to assess the effect of soil water storage capacity on yield. The model reasonably simulated total biomass and seed yield of soybean both in moisture-deficit tropical situations and in cooler temperate and subtropical locations.
- Simulation results showed that in 70% of years, total runoff for BBF was >35 mm compared to flat landforms (>60 mm). On the medium-deep soil it was >70 mm for BBF and >80 mm for the flat landforms.

- The simulated soybean yields were >2200 kg ha^{-1} and were not influenced by landform or soil depth. Simulated chickpea yields were higher in medium-deep soils than in shallow soils.

Conclusions

- BBF landforms reduced runoff till the soil profile was fully charged and more water was stored in the soil profile than in the flat land.
- Improved management practices identified here were incorporation of FYM as a practical option for improving nutrient budgeting under rainfed cultivation and use of *Gliricidia*, a N-fixing species to enhance soil fertility.
- The integration of organic and inorganic nutrient sources is a rational strategy for efficient use of scarce resources to increase and sustain crop yields and soil fertility status.
- This experiment has an integrated use of organic manure such as FYM, incorporation of *Gliricidia* loppings, and fertilizer P application. In BBF landform this was found to be effective for crop productivity as well as sustainability.
- This watershed approach clearly demonstrated that increased productivity can be obtained from rainfed systems.
- This approach further helped in improving the soil quality and reducing soil degradation.

Integrated Management of Adarsha Watershed, Kothapally, Andhra Pradesh, India

Background

Adarsha watershed at Kothapally, in Ranga Reddy district of Andhra Pradesh, India is one of the on-farm benchmark sites for the ADB-assisted project "Improving Management of Natural Resources for Sustainable Rainfed Agriculture". The M Venkatarangaiya Foundation (MVF), a non-governmental organization, Drought Prone Area Programme (DPAP), Government of Andhra Pradesh, and ICRISAT selected this watershed in Shankarpally Mandal, Ranga Reddy district for evaluating the integrated watershed management option to improve rainfed agricultural production and thus reduce poverty of the farmers through increased systems productivity. It is located at 78° 5' to 78° 8' E and 17° 21' to 17° 24' N falling in Survey of India toposheet No. 56 Kl 3. The landscape of the watershed is made up of Vertisols and associated Vertic soils (90% of the area); Alfisols (10% of the area) are also present. The main rainy season crops grown are sorghum, maize, cotton, sunflower, mung bean, and pigeonpea. In the postrainy season sorghum, sunflower, vegetables, and chickpea are grown. Wheat and rice are also cultivated. The annual rainfall of Shankarpally area is about 800 mm received mainly in June to October (85%).

Objectives

The main objective of this on-farm research is to increase the production in this watershed through increased efficiency of natural resources such as rain water while maintaining or improving the land and environment. The specific objectives are to:

- Increase systems productivity through crop intensification by increased adoption of improved soil, water, nutrient, and pest management technologies;
- Increase rain water use efficiency for agricultural production through increased soil moisture, storing harvested excess runoff water, and increased groundwater recharging; and
- Evaluate suitable cropping systems based on the agro-ecological potential of the region.

The strategy

The strategy followed is to encourage maximum people's participation in planning and execution of watershed activities. Farmers' committees have been formed and all decisions are taken by the farmers. Appropriate decisions are facilitated by providing all the necessary technical support by the scientists and extension workers. Within a large watershed, micro-watershed is selected as demonstration block for appreciating the benefits in terms of reduced runoff and soil loss through scientific measurements in developed and undeveloped micro-watersheds. Farmers in rest of the watershed are involved in evaluating land, nutrient, and water management options along with pest management for improved crops and systems. Farmers are also involved in nutrient budgeting studies and response to specific nutrients for different systems.

Our Partners

- M Venkatarangaiya Foundation (MVF)
- Drought Prone Area Programme (DPAP), Government of Andhra Pradesh
- Central Research Institute for Dryland Agriculture (CRIDA)
- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
- Farmers in Adarsha watershed

Baseline survey

- A micro-watershed of 30 ha within the watershed of 500 ha is delineated. A detailed topographic survey was completed. The watershed is equipped with hydro-meteorological equipment for measuring weather, runoff, and soil loss measurements. A detailed socioeconomic and crop productivity survey of all the 29 farming families from this micro-watershed and of 25% randomly selected households from each group of farm holding (small, medium, and big) families from the watershed was completed. Total number of households in the watershed is 270, of which 250 families are having land and 20 families are landless. Total village population is 1492. Fifty per cent of the families have <1 ha land, 22% families have 1 to 2 ha of land, and 27% families have >2 ha land per family, of which 24% own an average of 8 ha per family. GIS maps indicating soil type, soil depth, and crops grown during rainy and postrainy seasons have been prepared (Figs. 4 and 5). The soil depth maps are prepared based on the information provided by the farmers and the information was verified through random samplings.

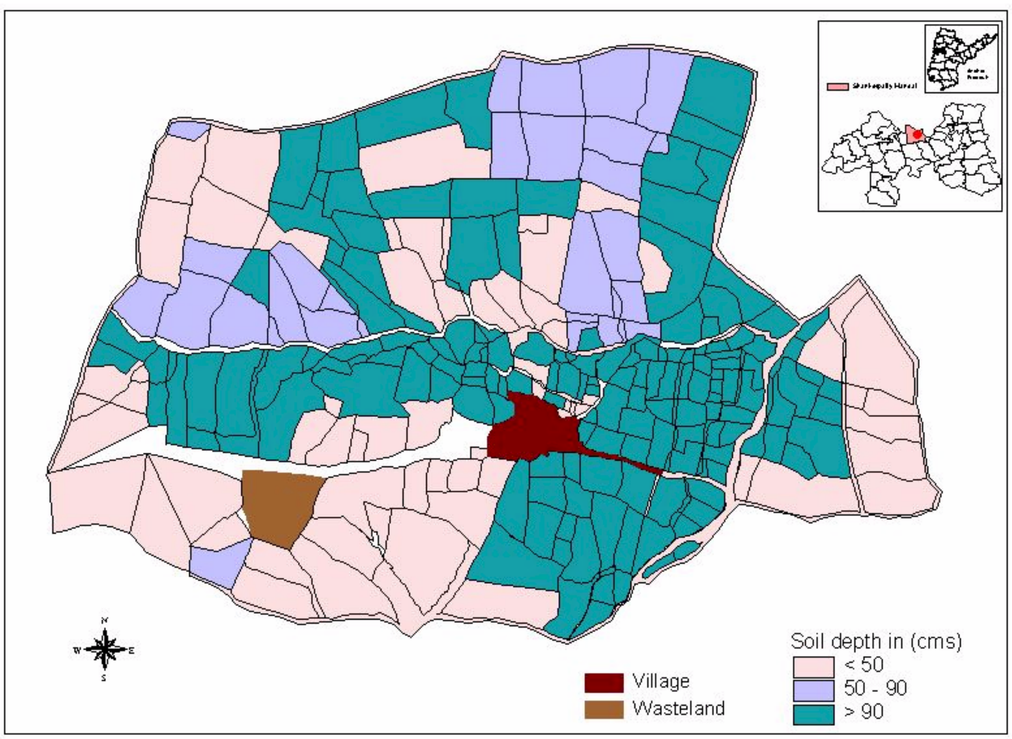

Figure 4. Soil depth map of Adarsha watershed, Kothpally, India.

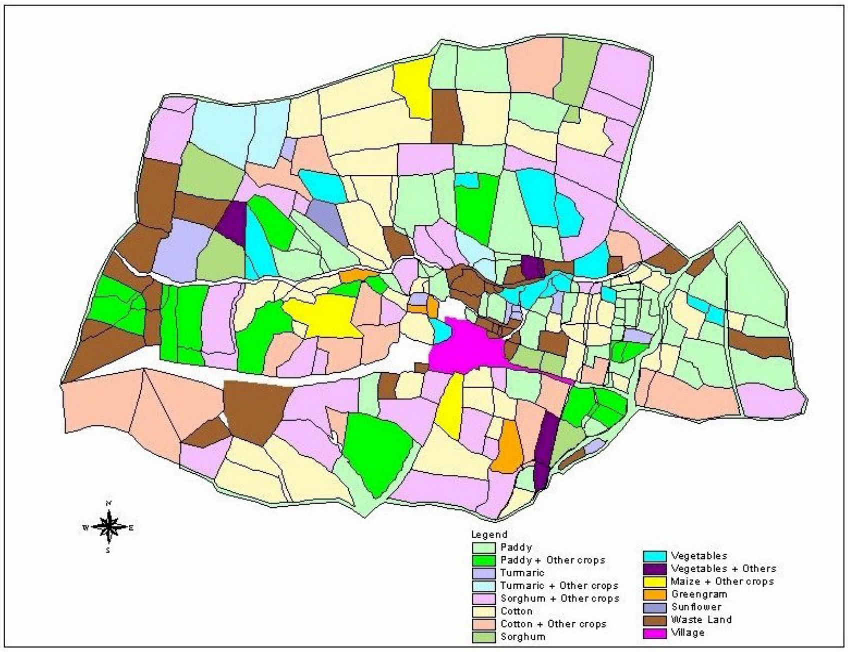

Figure 5. Crops grown in Adarsha watershed during 1998 rainy season.

- Small and medium land-holding farmers grow sorghum intercropped with pigeonpea, rice, cotton, and turmeric. Large size landholders grow cash and food crops evenly whereas small and medium size landholders grow more food crops than cash crops. Most of the farmers use DAP and urea; however, there is an inverse relationship between land-holding size and quantity of DAP used. Farmers use FYM and poultry manure (compost) in varying quantities of 1200 to 6250 kg ha^{-1} at different intervals.
- Weekly weather data for last 5 years from the nearby *Mandal* is collected and is being processed.
- The GIS-based watershed data management system for Adarsha watershed has been developed. All the watershed data are compiled in GIS format so that comparative assessment for impact monitoring exercise will be easy.
- Satellite data for pre-watershed and post-watershed periods are collected and are being analyzed.

Site characterization

The soil in the fields of micro-watershed was sampled up to a depth of 90 cm for detailed biological, chemical and physical characterization. Shallow soils contain 55.2% clay in top 15 cm and medium depth soils contained 61.7% clay. With increasing depth up to 90 cm clay content decreased. At field capacity soil moisture content varied from 40% to 42% for shallow and medium-deep soils. These soils are low in available P content (1.4 to 2.2 mg kg^{-1} soil), zinc, B, and S content in addition to low organic C and mineral N content. Average mineral N content was 11 mg N kg^{-1} soil at 0–15 cm depth and 4.5 mg N kg^{-1} soil for 60–90 cm depth. Mean soil respiration was 142 mg C kg^{-1} soil at 0–15 cm depth and 59 mg kg^{-1} soil for 60–90 cm depth. Microbial biomass C was 278 mg C kg^{-1} soil at 0–15 cm depth and 85 mg C kg^{-1} soil at 60–90 cm depth. The biomass C was more in medium-deep soils (182 mg C kg^{-1} soil) compared to shallow soils (172 mg C kg^{-1} soil). Microbial biomass N was 44 mg N kg^{-1} soil at 0–15 cm depth soil and 13.5 mg N kg^{-1} soil at 60–90 cm depth soil. Net N mineralization was more in medium-deep soils (1.21 mg N kg^{-1} soil $10d^{-1}$) than shallow soils (0.63 mg N kg^{-1} soil $10d^{-1}$). With more soil respiration, more microbial activity resulted in more net N mineralization. This increase in biological activity could result in increased nutrient availability in the soil. Soil samples from two toposequence fields up to a depth of 90 cm are collected and are being processed for detailed characterization and productivity.

Continuous monitoring of weather parameters

An automatic weather station is located at 17° 22' N and 78° 07' E and about 550 m above mean sea level. All the weather parameters were continuously monitored through this station. This was operational from beginning of the monsoon in June 1999. Various weather parameters were recorded. The total rainfall was 559 mm which is actually 30% below normal rainfall for the region. There were 49 rainy days in 1999. Rainfall variability was measured with four manual raingauges located across the watershed. Other meteorological parameters recorded were solar radiation, air temperature, soil temperatures at 5 cm, 10 cm, and 20 cm depths, wind velocity, and wind direction. These parameters were recorded at hourly intervals regularly.

Groundwater monitoring

For monitoring the groundwater levels within the watershed, there are 54 open wells and all these are geo-referenced. These are being monitored at fortnightly intervals throughout the year. Fifteen bore wells are also existing within this watershed area. Runoff, and soil and nutrient losses are monitored using automatic water level recorders and sediment samplers.

Soil and water conservation measures

For increased water and soil conservation, various options such as landform treatments (e.g., BBF, contour planting), waterways and drainage channels, field bunding, wasteland development, vegetation, storage of excess water through construction of check-dams, dugout ponds, gabion structures, and gully plugging, and increased cropping are undertaken in the watershed.

- The soil and water conservation measures included identification of 21 potential sites for water storage structures, 270 sites for gully control structures, and 27 ha for field bunding.
- Forty-seven gully control structures were constructed in the watershed.
- Field bunding in 27 ha is completed.
- Four water storage structures, one earthen and three masonary structures with a capacity of 300 to 2000 m^3 were constructed during the first year (1999) of development of the watershed.
- Thirty thousand *Gliricidia* plants were planted on the field property bunds by the farmers for stabilizing the bunds to conserve rain water and soil. In addition these plants will

generate N-rich organic matter for field application which will augment the N supply for the crop growth and reduce the dependence on mineral fertilizer N.

- Common wasteland treatment has been initiated.
- Tree plantation along the roads and field bunds is undertaken.
- For soil conservation a gabion structure is constructed and more are planned.

Integrated nutrient management trials

- During 1999 season 24 farmers conducted trials by applying recommended fertilizer doses to the improved varieties of crops.
- Pigeonpea and soybean seeds were inoculated by the farmers with appropriate *Rhizobium* culture.
- Quantification of BNF in farmers' fields was done by N-difference method using non-fixing crops such as sorghum (varieties of matching duration) with soybean and medium-duration pigeonpea.
- Farmers have planted 30,000 *Gliricidia* seedlings on farm bunds for producing N-rich organic matter on their farms.
- Few farmers have started vermi-composting using *Parthenium* weed, rock phosphate, and earthworms.
- During rainy season of 2000, 30 farmers are conducting nutrient budgeting trials and also response to B, S, and B+S for different crops/cropping systems.
- Farmers (male and female) were trained in INM options and vermi-composting.

Integrated pest management

- Pheromone traps are put in the watershed to monitor *Helicoverpa* moth population.
- Two youths were trained in production of nuclear polyhedrosis virus (NPV) for controlling *Helicoverpa*. A NPV production unit at village level is planned.
- Farmers were exposed to IPM methods through video show and specialized lectures.
- A NPV production unit in this village is planned using the self-help youth group.

Productivity and sustainability

In 1999, the improved management practices such as sowing on BBF system, flat sowing on contour, sowing and fertilizer application with the help of improved bullock-drawn tropicultor, and application of suitable fertilizer doses were evaluated by the farmers. Also improved varieties in improved cropping systems were evaluated: soybean (PK472) followed by chickpea (1CCC 37), maize (DH 103) intercropped with medium-duration pigeonpea (ICPL 87119), and sorghum (CSV 15) intercropped with medium-duration pigeonpea (ICPL 87119).

- Maize yields ranged from 2250 to 3250 kg ha^{-1} and pigeonpea yields ranged from 570 to 710 kg ha^{-1}. Average productivity of 3300 kg ha^{-1} of maize/pigeonpea intercropping system was obtained by several farmers in 1999.

- Average productivity of sorghum/pigeonpea system was 1570 kg ha^{-1} (1135 kg sorghum ha^{-1} and 435 kg pigeonpea ha^{-1}) as compared to only 900 kg ha^{-1} from traditional sorghum/ pigeonpea intercropping system which was followed by the farmers.
- Soybean yields ranged from 400 to 1200 kg ha^{-1} depending on the soil type.

Due to unfavorable soil moisture conditions the postrainy season chickpea crop was not sown. Along with the highest systems productivity the cost-benefit ratio of the improved systems was more (1:3.47) compared to the farmer adopted systems. There was not much difference in the cost of cultivation between the improved and traditional systems, whereas in terms of profit gained the maize/pigeonpea and sorghum/pigeonpea intercropping systems were found to be more income yielding to the farmers when compared to the traditional systems. The same trials are being conducted in 2000 also.

During the rainy season of 2000, 30 farmers are evaluating improved management systems such as BBF, tropicultor for sowing and inter-culturing, recommended doses of fertilizers, and improved seeds of maize, pigeonpea, sorghum, and soybean.

Many more activities covering the above mentioned areas are planned to be undertaken throughout the watershed. Suggestions from workshop participants will help to make this watershed really a good “model watershed” as its name “Adarsha Watershed” indicates.

Observations and Suggestions – *R K Gupta*

The traveling workshop-cum-field visit to various benchmark watersheds enabled the participants to get hands-on experience on NRM. Besides it offered an unique opportunity to get an exposure to ground realities/problems encountered and views of farmers belonging to different agro-ecoregions and socioeconomic settings. Mutual discussion among the participants of the workshop during and after the visit to each watershed were quite useful and revealing. The observations made and suggestions for each watershed are narrated below.

Thanh Ha watershed

The Thanh Ha watershed in Vietnam represents rainfed lands occurring on moderate to high slopes. In spite of high amount of rainfall received annually, occurrence of prolonged dry-spells is encountered leading to significant fall in crop performance. Erosion of soil and plant nutrients from cultivated lands is very high.

A significant progress in implementing the planned program for the watershed has been made. Constraints to crop productivity have been clearly identified and natural resource base characterized. Massive plantation and excellent growth of *Gliricidia* saplings on contour bunds achieved in the watershed has begun to reduce soil erosion. Trenches dug across the slope in the upper reaches and water percolation ponds dug in the watershed are further contributing to the conservation of soil and rain water.

Suggestions:

- Runoff samples should be analyzed for N, P, K, and S so as to assess seasonal loss of plant nutrients from treated and untreated areas in the watershed.
- Adaptive research on soybean/maize intercropping should be carried out to provide an acceptable and more remunerative cropping system to the farmers.
- Use of engineering structures on steep slopes for control of erosion is essential.

Tad Fa watershed

The Tad Fa watershed in northeastern Thailand represents rolling topography and medium- to heavy-texture soils. Rainfall is bimodal, fairly high, and spread over eight months in a year. Soil erosion and land degradation are serious problems. Lack of tenancy rights to the farmers is also proving to be a disincentive to the farmers for taking up long-term soil water conservation measures.

Soils of the watershed have been characterized and runoff and soil losses are being assessed. Soil conservation measures have also been initiated. Terrace cultivation demonstrated in the area by the State Government holds promise.

Suggestions:

- Hillocks with diminishing soil cover should be put under agri-horticulture or agroforestry production systems.

- Vegetative bunds of locally adapted grass species should be tested for reducing erosion on moderate slopes. Agave should be tested for its usefulness as a vegetative barrier.

Ringnodia watershed and JNKVV watershed

Ringnodia watershed near Indore, Madhya Pradesh, India represents rainfed black soil regions with medium to deep soil cover. The major constraints are erosion of soil and plant nutrients, occurrence of prolonged dry-spells, and oxygen stress in July and August.

Major activities undertaken include construction of diversion bunds for safe disposal of runoff from upper reaches, demonstration of ridge planting and its effect on performance of soybean, and construction of loose boulder structures (where necessary) and water harvesting structures. Other activities undertaken include testing of improved varieties of pigeonpea and soybean, integrated plant nutrient system (IPNS), soil test-based nutrient use, etc.

The micro-watershed at the College of Agriculture, JNKVV, Indore represents rainfed deep black soil region with relatively flat topography. Emphasis is being laid on improving productivity of soybean-based cropping system through improved drainage. The BBF system though not statistically superior to flat bed planting has proven to be useful in conservation of rain water and use efficiency of rain water and applied plant nutrients, particularly in the long-term.

Suggestions:

- Farmers' participation in watershed management needs to be encouraged.
- Production of quality compost using farm residues and its use as an integral part of INM.

Lalatora watershed

Lalatora watershed is located in the central part of the state of Madhya Pradesh. The soils are generally clayey in texture, deep, and have high water retentivity. They are, however, highly prone to erosion and waterlogging during rainy season.

Resource characterization through basic surveys, use of remote sensing techniques, and ground studies has been accomplished. Studies on introduction of improved crop varieties, land configurations involving BBF, nutrient management studies with emphasis on secondary and micronutrients, and zero tillage for postrainy season crop are in progress.

The crop condition in the entire watershed was very good. Farmers' participation in watershed activities was enormous. The farmers were aware of the pros and cons of the activities being carried out in the watershed.

Suggestions:

- It has been established beyond doubt that any land configuration including BBF ensures drainage, and reduced velocity of runoff will improve productivity of rainfed crops and enhance sustainability. There is a need to critically assess the reasons for non-acceptance of such practices on large scale by the farmers.

- A cost-effective, affordable ridger-cum-planter should be developed and tested at a few locations in black soil region.
- Loss of nutrients due to runoff from treated and untreated watershed areas should be monitored.

IISS watershed

The watershed developed at the research farm of IISS, Bhopal, Madhya Pradesh represents black soil regions under moderate rainfall. Studies aimed at improving productivity of rainfed soybean-based cropping systems have been initiated. Emphasis is being laid on quantification of effect of waterlogging, land configurations, and nutrient management strategies on productivity of soybean crop.

Suggestions:

- Waterlogging treatments should be based on field situations that exist during a normal rainfall year.
- BBF and crop rows have been developed along the slope. This is bound to increase runoff and erosion. To reduce runoff and erosion, the configurations should be developed along contours on a grade.
- *Gliricidia* is being grown on land capable of supporting two crops in a sequence. Farmers would not and should not sacrifice a good quality land with virtually no limitations only for production of biomass. It is therefore suggested that bunds may be utilized for the purpose. Alternatively *Gliricidia* should be planted on land with shallow soil depth.

BW7 watershed

The BW7 watershed at the research farm of ICRISAT, Patancheru, Andhra Pradesh, India represents Vertic Inceptisols commonly known as medium black soils. The soils possess high water retention capacity and yet they remain prone to waterlogging, runoff-induced erosion, and depletion of fertility.

Emphasis is on use of BBF system for improving drainage, infiltration of rain water into soil, reduction of soil erosion, and soil fertility. An attempt is also being made to minimize use of chemical fertilizer by opting for alternative sources such as BNF, *Gliricidia* loppings, and FYM. The BBF system has contributed towards deep drainage, BNF, and recovery of plant nutrients by soybean, pigeonpea, and chickpea crops.

Suggestions:

- Various components of N and S balance should be estimated separately for flat and BBF systems.
- SEm should be worked out and indicated along with figures of runoff, deep drainage, soil evaporation, and evapotranspiration.

Adarsha watershed

The soils of the Adarsha watershed at Kothapally, Andhra Pradesh, India are clayey and test low in major and secondary nutrients. Major constraints to productivity and sustainability are waterlogging, soil erosion, and depleted soil fertility.

Activities in progress are construction of gully control structures, bunding of fields, construction of water harvesting and storage structures, plantation of *Gliricidia*, treatment of common lands, etc. Farmers actively participated in all activities. A striking feature of the watershed is that institutions created by the farmers such as watershed committee have taken up complete responsibility of program implementation and maintenance of accounts although four different agencies are involved in offering technical guidance and supervising developmental activities. Public audit system is another noticeable feature. Holistic approach to watershed management was very conspicuous. Integrated pest management (IPM) and INM practices were observed to be taken up vigorously and enthusiastically.

Suggestions:

- Agave was observed to perform well in the watershed area. The plant can be used for stabilizing gully banks.
- There is scope for improving the design of gabion structures.

General remarks

- Land capability-based land use should be initiated in all watersheds.

Observations and Suggestions – *Nguyen Van Viet*

The traveling workshop to visit different watersheds in Vietnam, Thailand, and India provided good opportunity to scientists to learn more about watershed management. It provided an opportunity to exchange opinions amongst project team members and also to meet and discuss the problems and solutions with the farmers in these countries. My observations and suggestions for different watersheds are listed below.

Thanh Ha watershed

- Area of Thanh Ha watershed in Vietnam is 1522 ha; 53% is suitable for arable cropping; and 7% is under reserve forests. Total rainfall is 1300–1500 mm. Monocropping with maize (February–June) followed by maize (July–November) is predominant.
- The key constraints are drought, soil erosion, pests and diseases, lack of capital, and weak agricultural extension.

Activities:

- Quantification of natural resource base has been done.
- Watershed development:
  - Characterization of physical, chemical, and biological properties of soil to a depth of 1.5 m has been done.
  - The topo maps were prepared.
  - Three percolation tanks were dug.
  - Two micro-watersheds have been delineated and equipped for monitoring runoff and soil loss.
  - Water level of twelve open wells is being monitored.
  - Water collection trenches and silt traps were dug. The waterways were stabilized and grassed.
  - For stabilization of bunds, 10,000 *Gliricidia* saplings were planted, and 10,000 saplings were ready for next plantation.
  - New grass species are being evaluated to control erosion.
- Improved practices and cropping systems:
  - The newly introduced improved cropping systems with legumes (groundnut, soybean, mung bean) gave higher income than traditional maize-maize cropping system. The area of legumes increased from 2% to 50%.
  - Improved production practices [such as improved variety, INM, IPM, and integrated disease management (IDM)] were evaluated.
  - Application of FYM and biofertilizers were evaluated in farmers' fields.
- Farmer participation programs:
  - Two farmers' field days were organized.
  - A training course on IPM for farmers was conducted.
  - Eighteen farmers participated in on-farm experiments.

Tad Fa watershed

Tad Fa watershed is located in northeastern Thailand. The area of the micro-watershed is 15 ha, with 7 farmers. The annual rainfall is 1100–1800 mm. Erosion and runoff are very high. The main crops are maize, legumes, and fruit trees. The major problems are weeds and pests; forest fires; drought; soil erosion; and farming is not a viable occupation.

Activities:

- Survey of the benchmark watershed:
  - A map of the watershed has been prepared.
  - A survey on crop and cropping systems was conducted.
  - A survey on water reservoirs was also carried out.
- Physio-chemical properties of soil to a depth of 110 cm in 13 farmers' fields were analyzed.
- Evaluation of crops:
  - The evaluation of maize yield was done in 1999.
  - Yield trial of groundnut varieties was done in 1999.
  - The test for possibility of growing soybean was conducted.
  - Observations on the yields of upland rice were noted.
  - New cropping systems were tested in 2000: maize; maize-legumes sequential cropping (maize-soybean, maize-groundnut); and intercropping of fruit trees with maize.
- Environment measurement:
  - Soil loss assessment from water runoff.
  - Automatic weather station is posing problems of installation.

Ringnodia watershed

The total area of Ringnodia watershed in Madhya Pradesh, India is 2290 ha. Area of the micro-watershed is 390 ha. Rainfall is 960 mm. Nearly 40% of the total rainfall is lost as runoff. The slope of the watershed is 2–8%. The soils are shallow to deep black. About 95% of the land is used for soybean production during the rainy season (June–October). During the postrainy season, the land is used for wheat (75%), chickpea (15%), and other winter crops (10%). The major problems are water stagnation; poor drainage; low germination in soybean; soil erosion; and no water harvesting during rainy season.

Activities:

- Soil and water conservation:
  - Water storage structures in three segments of the watershed have been constructed.
  - Effect of these structures on groundwater is being monitored.
  - A water diversion bund of 275 m length was constructed.
  - Topographic survey of 60 ha was completed.
  - Sediment sampler and thalamides to record runoff have been installed.
- Crop production:
  - Medium-duration pigeonpea has been tested as an intercrop with soybean and as a pure crop.
  - Extra-short-duration pigeonpea cultivars have been introduced.
  - Use of reduced levels of N and P and biofertilizer is being tested.

JNKVV watershed

JNKVV micro-watershed is located in the College of Agriculture, JNKVV, Indore, Madhya Pradesh. The area of the micro-watershed is 2 ha. The BBF and flat bed systems were compared for various cropping systems. Soybean/pigeonpea intercropping system, and soybean followed by chickpea, wheat, and linseed crops during postrainy season were tested. The productivity was similar on BBF and flat beds. Soybean/pigeonpea intercropping system could sustain adverse weather conditions and utilize residual moisture effectively. Installation of runoff and soil loss equipment was completed.

Lalatora watershed

The area of Lalatora watershed is 10,525 ha. The altitude is 415 m above sea level (asl). The total rainfall is 1300 mm. The major constraints are runoff and soil loss, waterlogging, degraded soil, low rain water use efficiency, groundwater depletion, low cropping intensity, and resource-poor farmers.

Activities:

- Watershed development:
  - Check dams, farm ponds, percolation tanks, and bunds were constructed.
  - Runoff and soil loss equipment and automatic weather station were installed.
- Improved practices:
  - BBF system is being evaluated.
  - Micro-nutrients in the form of borax (10 kg ha^{-1}) and gypsum (200 kg ha^{-1}) were used.
  - Seed treatment of soybean variety JS 335 with biofertilizers and quantification of N_2 fixed by the soybean crop using maize as non-fixing crop.

IISS watershed

The altitude is 490 m asl. The total rainfall is 1130 mm. The storage capacity of the reservoir is 2.5 ha-m with 2 m depth. About 1.5 ha land is developed for testing BBF and flat systems. About 1 ha land is being used for an experiment on soybean-based cropping systems.

Activities:

- An experiment on effect of irrigation and nutrient management on soybean-wheat system and land treatment (BBF and FOG) was conducted.
- An experiment on evaluation of soybean-based cropping systems under different irrigation and nutrient management treatments was also conducted.
- An experiment on impact of waterlogging on soybean was carried out.

BW7 Watershed

About 72 million ha of land in India constitutes black soils. Of this, 60 million ha are Vertic Inceptisols which are prone to severe land degradation. The BW7 watershed at ICRISAT, India represents Vertic Inceptisols.

Major constraints:

- Inappropriate land and water management practices.
- High runoff and soil erosion.
- Depletion of soil nutrients and organic matter soil.
- Waterlogging.
- Cropping intensity.

Activities:

- Watershed development:
  - The whole watershed is divided into shallow (<50 cm soil depth) and medium depth (>50–90 cm) blocks.
  - Each block is divided into BBF and flat land form systems.
  - There are four hydrological units with two soil depths.
- Crop production and practices:
  - Cropping systems: soybean-chickpea; soybean-pigeonpea.
  - BBF and flat land form are prepared before rainy season.
  - Soybean seed was treated with *Bradyrhizobium*.
  - FYM and *Gliricidia* loppings were applied.
  - Appropriate IPM and IDM strategies were implemented.

Adarsha watershed

The watershed area is 500 ha. The micro-watershed area is 30 ha with 29 families. The altitude is 550 m asl. The total rainfall was 559 mm in 1999.

Activities:

- Soil and water conservation measures:
  - Several gully control structures were constructed.
  - Field bunding in 27 ha has been completed.
  - Four water storage structures with a capacity of 300 to 2000 m^3 were constructed.
  - About 30,000 *Gliricidia* plants were planted for stabilizing the bunds.
- INM trial: Applying recommended fertilizer; treatment of *Rhizobium* culture; producing N-rich organic matter by planting 30,000 *Gliricidia* plants; conducting nutrient budgeting trial; and test response to B, S, and B+S for different crops.
- IPM: Pheromone traps were set up to monitor *Helicoverpa* moth. A NPV production unit at village level is established.
- Improved management practices were evaluated: Sowing on BBF system; flat sowing on contour; sowing and fertilizer application with the help of improved bullock-drawn tropicultor; and application of suitable fertilizer doses.

General remarks

- The collection of various hydrological and soil related data in most of the watersheds was good.

- The land and water management development and research work in most of the watersheds was good.
- Research in INM was started in most of the watersheds.
- Evaluation of improved practices and cropping systems is in progress. The new crops and cropping systems in most of the watersheds gave higher income than the old systems.
- In most of the watersheds farmers were involved in watershed works.
- The soil and water conservation works in most of the watersheds were good.
- Every watershed has specific problems. We cannot compare the work of one watershed with another. Specific suggestions for some watersheds are given below:
    - At Tad Fa watershed *Gliricidia* can be planted on contour bunds for stabilizing the bunds.
    - Efforts to conserve soil and water can be increased to minimize land degradation with active help from the farmers at Tad Fa and Ringnodia watersheds.
    - Increased use of green manure in Thanh Ha, Tad Fa, and Lalatora watersheds.
    - Farmers' participation in watershed activities in Ringnodia watershed could be improved.

Observations and Suggestions – *Banyong Toomsaen and C Lusanandana*

This report summarizes the activities of the authors during the traveling workshop-cum-field visit to benchmark watersheds from 27 August to 12 September 2000 as well as the authors' opinions after visiting different watersheds in the three countries visited.

27 August 2000

Left Khon Kaen for Bangkok, then Bangkok to Hanoi. We were welcomed at the airport by Dr A Ramakrishna and Dr N V Viet. We checked in the hotel MOD Palace, and later met Dr S P Wani from ICRISAT and other scientists from India namely Dr R K Gupta, Dr K P Raverkar, and Dr A B Pande.

28 August 2000

The inauguration of the Traveling Workshop at VASI, Thanh Tri, Hanoi, Vietnam was presided by Dr T D Long. Dr S P Wani explained the project and workshop objectives, modalities, and details of the workshop. Dr T D Long introduced VASI staff members to the participants and later the participants visited different laboratories at VASI. The authors were impressed by the contribution of VASI to agricultural development in Vietnam. Many new varieties of crops, especially rice, soybean, and groundnut have been released by VASI. Hybrid rice is also being produced by the Institute.

In the afternoon, we visited the National Institute of Planning and Projection of Vietnam and were welcomed by Dr N Khang, Deputy Director of the Institute and his staff members. We visited remote sensing centers and the soil analysis laboratory. The center has catalog digital database of soil map, temperature map, rainfall map, land mapping unit (LMU), present land use map (1994), land use planning map, geomorphology map, climate region map, inudate map, average radiation map, ecological map, agro-ecological zoning map, and ecological map for the whole country (scale 1:1,000,000). At regional level, the center also has catalog digital database of agro-ecological zoning map, soil maps, LMU, and present land use map (1996) for 9 agro-ecological zones (scale 1:250,000); and LMU present land use map, suitability for some crops, temperature map, rainfall map, and hydrological map for central highland (scale 1:250,000).

We later visited the Institute of Biotechnology (IBT) at Nghia De, To Lium and were welcomed by the Director of the Institute, Dr Le Tran Dinh. The research activities of the institute involve molecular biology and genetic engineering, biotechnology of microorganisms, enzyme biotechnology, plant biotechnology, and animal biotechnology. The main achievements are: (i) chill and drought tolerant rice cultivars DR 1 and DR 2; (ii) micropropagation of tropical crops, e.g., sugarcane, banana, agave, pineapple, etc; (iii) development of biofertilizers for rice, legumes, and fruit crops; (iv) embryo transfer in cattle and dry preservation of sperms; (v) development of pharmaceutical products, e.g., Biolactovin and Pluriumin; (vi) molecular cloning and expression of protease and amylase genes, genes relating to chill tolerance in rice. We were impressed by the work done by the Institute and were happy to hear that the government has realized the importance of biotechnology and has given quite a handsome sum of money to build up the laboratory facilities.

29 August 2000

We visited the Thanh Ha watershed which is located in Thanh Ha State Farm, Kim Boi district, Hoa Binh province and is 70 km southwest of Hanoi. The area of the watershed was previously owned by the government but later distributed to the farmers (approximately 0.6 ha per family). Maize-maize is a dominant cropping pattern in the region. We visited the fields where experiments are being conducted. We saw the rainguage that has been installed and digital recorders to monitor runoff from the treated and non-treated areas. Three recharging ponds (3 × 4 × 1 m) were dug to capture runoff water and serve as percolation tanks. Water collection trenches were dug along the contours on the upper part of the toposequence for collection and storage of runoff. Grass was grown in the waterways to stabilize them. Silt traps were dug in the waterways. *Gliricidia* saplings were planted on the contour bunds to strengthen the resistance and stability of the bunds.

Ruzi grass (*Brachiaria ruziziensis*) was introduced to stabilize the contour bund. Farmers in the area are eager to adopt the new cropping pattern introduced by the researchers instead of growing maize followed by maize as previously done. Groundnut followed by maize gave the highest income to the farmers. The farmers are willing to participate in the activity of conserving soil moisture even though they have to sacrifice the crop plants. Cassava grown near the percolation tank grows better than that grown in the area far away from the pond. An experiment on different soil conservation methods on growth and yield of groundnut was also shown. In general, we were impressed by the work done in the watershed especially when we learned that the cropping systems involving groundnut, soybean, and mung bean are new and being adopted by the farmers in the same watershed and some big farmers outside the watershed also. Our suggestions to improve the watershed are as follows:

- The rain guage for measuring the rainfall should not be close to the trees; the project may have to pay some money to make the farmers cut down banana plants and other fruit trees near the rainguage. Only short plants and vegetables should be grown in the area where the rainguage is installed.
- We have seen that soil moisture conservation using plastic mulch is being studied along with other methods for groundnut production. Is it possible to study the benefit-cost ratio in this trial?
- We have also observed that groundnut-maize cropping system gave the highest return and is likely to be accepted by the farmers. Would there be any market problem with groundnut in the future when this cropping system is widely accepted? This question can be applied to soybean and mung bean.

30 August 2000

Left Vietnam to Bangkok and stayed overnight in Bangkok.

31 August 2000

Left Bangkok for Khon Kaen in the morning. Dr S M Virmani gave an overview of the project: Improving management of natural resources for sustainable rainfed agriculture in the sloping land of northeastern Thailand. This was followed by a discussion.

01 September 2000

We visited Tad Fa watershed. This watershed is situated 120 km west of Khon Kaen in Thailand. The annual rainfall is 1100–1800 mm. The main crops are maize-maize, legumes, and fruit trees. The topography is hilly; 30% of the area has >15% slope, 50% of the area has <15% slope, and 20% of the area has 2–5% slope. The soils are coarse Alfisols: Kandiustalfs. Erosion and runoff are very high. Farmers own 3–5 ha land per family. Maize yields are high (3–4 t ha^{-1}). The failure of the first crop in maize-maize system is once in 3 years and that of the second crop is once in 10 years. Fertilizer use is high (about 200 kg ha^{-1}). Fruits are grown on flat lands having 2–5% slope. Farmers are poor and do not want to invest in land (on soil conservation) because of a problem of land tenure. Weeds and pests are major problems. Forest fires are also a problem. Drought is a problem during the dry season. Fruit trees give low production in steep slopes. Farming is not a viable occupation; off-farm work opportunities are low. There is a migration of labor especially among educated children who take employment in nearby cities.

We visited the area where the instruments for measuring runoff and erosion are located. Runoff and erosion are being monitored from the annual and fruit trees-based systems. Vegetable crops such as cabbage are grown. Sunn hemp, groundnut, and rice are grown between fruit tree rows. Some ponds have been dug in the area by the Land Development Department. We talked to a farmer who owns the land and found that he had to burn the plant residue to prevent forest fire and for convenience of soil preparation. The farmer broadcasts sunn hemp for seed production. The bed of vegetable crops was arranged along the slope and not against the slope. We also noticed that relay cropping systems of maize-rice bean and maize-cowpea are being studied. We suggest the following measures to introduce sustainable farming:

- Convince the farmers to grow the crop against the slope.
- Convince the farmers to grow sunn hemp in rows to get a better stand and not to burn the stover of sunn hemp.
- Construct and stabilize the waterways either using gravel or grass. Construct gabion, silt trap, or sediment pond. Build water reservoir in the lowest part of the land to conserve the water for irrigation of vegetable crops.
- Convince the farmer not to burn the plant residue but plow the field soon after crop harvest. Also teach the farmer how to make compost and use it along with chemical fertilizer.
- IPM should also be included in the system. Farmers should be trained in safe-handling of chemicals.
- Farmers should be made aware of the importance of soil conservation.

02 September 2000

Left Khon Kaen for Bangkok and Bangkok for New Delhi.

03 September 2000

Left New Delhi for Indore.

04 September 2000

We visited Ringnodia watershed which is located about 15 km from Indore city on Indore-Ujain highway, in Madhya Pradesh, India. The average annual rainfall of the region is 960 mm. The total area of this micro-watershed is 390 ha. It has a recharge zone (>8% slope), a transition zone (2–8% slope), and a cultivated zone (<2% slope). The recharge zone comprises 18.2 ha, transition zone 20.8 ha, and the area under two ponds is 12.8 ha. The watershed has 19 tube wells, 14 open wells, and two large ponds. Most of the tube wells in this area are generally used for irrigating crops during the postrainy season but often dry up or run with reduced discharge from February onwards. The soils in the micro-watershed are deep black and shallow with variable depth. The topography consists of bare hill slopes to flat lands. The cultivated soils are mostly clay loam in texture with high moisture retention capacity, normal to alkaline (soil pH 6.5–8.5), and have low electrical conductivity (<1.00 dS m^{-1} at 25°C). Most soils are low to medium in basic soil fertility with respect to available K. The cropping patterns of the area are soybean (>95%), soybean mixed with maize, multi-cut fodder sorghum, and vegetables in the rainy season; winter crops are wheat (75%), chickpea (15%), and other crops (10%). Other crops include linseed, lentil, berseem, potato, onion, and garlic.

The ponds receive water from the hills; water diversion bunds as well as the gabion structures reduce the speed of the water. We asked a farmer about maintaining the diversion bunds and found that he is willing to maintain them. Pigeonpea has been introduced as an intercrop with soybean. We saw the weather station and the automatic instrument to measure erosion and runoff from the treated and non-treated areas. We are very much impressed with the effort to slow down the speed of the running water from the hill and the effort made to harvest the water. Our suggestions to introduce sustainable farming in the area are:

- Sowing pasture grasses or legumes on the hill side where nothing is grown at present. These crops should be able to produce seed and can be grown again next year. Control of grazing animals may be necessary if the pasture crops are to be established.
- Growing drought tolerant fruit trees (e.g., custard apple) in the hillside but control of grazing animals is of utmost importance. Besides, growing some drought tolerant fruit trees on the contour bunds may be another option.
- In the pigeonpea and soybean intercropping system, it was observed that pigeonpea was affected by some disease. A variety that is resistant to that particular disease may be required in the future.
- It is possible that the two ponds be used for fish culture and the nearby area may be used for growing vegetables during the summer months.

We later visited the experimental area of the College of Agriculture, JNKVV, Indore which is located in the campus itself. We saw the trial on pigeonpea stripcropped with soybean under BBF and flat bed systems. Automatic recorders of runoff and erosion were also observed. We observed that the slope of the area is very low and hence some doubts about its applicability in the farmers' fields.

05 September 2000

We visited Lalatora watershed. This watershed is located at Lalatora village of Vidisha district in Madhya Pradesh. The average annual rainfall of the region is 1,300 mm. The cropping systems are soybean followed by chickpea (instead of wheat as it needs at least 1 irrigation after soybean harvest). We also saw some fallow plots which were to be used to grow wheat in the winter months. We have seen the experiments comparing BBF planting of soybean vs flat planting. The experiments on the effect of S and B on soybean were also observed. The farmers told us that soybean treated with S and B had more nodules and he was expecting good crop yield this year. We also visited the area where automatic recorders of runoff and erosion were installed and were told that pasture grass especially S*tylosanthes hamata* was sown in the waterway. Our suggestions for sustainable farming in the area are:

- Propagate the idea of BBF planting and use of S and B in soybean production.
- Sowing *S. hamata* or other pasture legumes on the contour bunds. This will not only provide protein rich fodder for the animal but also stabilize the soil and prevent erosion. Legumes that reseed every year should be used.
- If possible, fruit trees or *Gliricidia* should be grown on contour bunds.
- The accessibility to utilize the water in storage pond should be considered.

06 September 2000

We visited IISS, Bhopal, Madhya Pradesh. We visited the fields where the impact of waterlogging on growth and yield of soybean is being studied and also the effect of G*liricidia* as alley crop with soybean is being compared with other cropping systems. Our suggestions are as follows:

- The treatments in the experiment should be relevant to the real farm situation.
- Examine if there is any problem of border row effect in the waterlogging experiment. Study the waterlogging effect in cement tank (if the real effect of waterlogging on soybean is required).

We later visited the Horticultural Station of JNKVV Agricultural College at Bhopal. The total area of the station is 20 ha. Fruit trees such as guava and mango are being grown. Various crops are grown between the fruit trees. The farm can generate an annual income of Rs. 2,00,000.

07 September 2000

Left Bhopal for Hyderabad via Bombay.

08 September 2000

In the morning we visited the Adarsha watershed which is located in Shankarpally Mandal, Ranga Reddy District and is about 40 km from ICRISAT, Patancheru. There are many organizations working in this watershed, i.e., MVF, DPAP, CRIDA, and ICRISAT. The main rainy season crops grown are sorghum, maize, cotton, sunflower, mung bean, and pigeonpea. The postrainy season crops are sorghum, sunflower, vegetables, and chickpea. Wheat and rice are also cultivated. When we went to the village we were met by the watershed committee and saw farmers preparing vermi-compost using the weed *Parthenium* sp, rock phosphate, and earthworms. The farmers learned the technique from ICRISAT and are now doing vermi-composting on their own. We went to the watershed where automatic recorders are being installed for measuring runoff; we also saw the weather station. We saw catchment ponds, silt trap, gabion with metal frame, and waterways with grass. *Gliricidia* plants were growing on contour bunds. We saw experiments comparing components of improved management system such as BBF, use of tropicultor for sowing and inter-culturing, recommended doses of fertilizers, and improved seed of maize, pigeonpea, sorghum, and soybean. We went to the communal grazing area where *Gliricidia* was just being planted. We visited a small dam being constructed in the waterway to collect water. We are very much impressed with the involvement of the farmers in the project and their willingness to accept the new technologies. We have some suggestions (or comments) for sustainable farming in the area:

- Is it possible to sow *S. hamata* on communal grazing area, paddy bund, or contour line? This will not only provide rich protein fodder but also stabilize the soil and provide N to the system through leaf fall. It can also reseed every year.
- Construct gabion structures without the metal frame; may be the structures like those in Ringnodia watershed are more suitable.

In the afternoon of the same day, we visited the BW7 watershed located at ICRISAT. We saw the weather station and the soil conservation measures to control erosion and runoff. Soybean intercropped with pigeonpea and *Gliricidia* were obviously visible. IPM (e.g., bird perch) was carefully being included in the program. We also visited the vermi-composting house. Our suggestions are as follows:

- Is it possible to calculate the income vs cost-benefit ratio in some experiments at least?
- Is it possible to measure the yield of earthworm in terms of dry weight and protein content and to use this protein in animal feed or fish culture?
- Is it possible to include in the system pasture legumes that can reseed?

09–11 September 2000

Report writing.

12 September 2000

Departed for Delhi and Bangkok.

Observations and Suggestions – *A B Pande*

The workshop-cum-field visit program was accomplished successfully as per the scheduled program without any problems. Some of the lessons learned, limitations observed, and suggestions made on each of the benchmark watershed visited during 27 August to 12 September 2000 are mentioned below.

Thanh Ha watershed

The Thanh Ha watershed seems to be one of the best watersheds.

Suggestions:

- Agave plantation on field bunds can be successful as it can prevent soil erosion on one hand and provide additional income to farmers (e.g., rope making) on the other.
- Loose boulder gully plugs instead of earthen ones can be more helpful in preventing soil erosion and reducing the runoff velocity of water.
- Vermi-culture can be introduced particularly in horticultural crops.
- More emphasis on organic manuring is needed.
- Strengthening the crop-livestock system will help in recycling the agricultural and animal outputs and will add to the family income.

New things observed:

- Various materials are being tried on experimental basis for moisture conservation by the farmers.
- Very good plantation of *Gliricidia* on bunds by the farmers.
- Very good coordination between farmers, extension workers, and scientists.

What to take home:

- Moisture conservation efforts.
- Strengthen team spirit.

Overall impression:

- One of the best watersheds visited.
- Good team spirit.
- Whole-hearted participation of workers and farmers.
- Team is willing to learn and shoulder new responsibilities.

Tad Fa watershed

Suggestions:

- Farmers' participation in activities needs to be improved.
- The number of farmers involved in trials is very low. It should be increased to at least 8–10.
- There is lot of scope to improve the team spirit in the multidisciplinary team representing various departments.
- More coordination efforts are needed to keep the team in harmony.
- There is much scope to improve the soil conservation techniques such as terracing, farm bunding, and vegetative barriers.

- Vermi-culture can be introduced particularly in horticulture plots.
- Pisciculture can be introduced in farm ponds having water for 6–8 months.

New things observed:
- Four agencies are working together in various activities of the watershed.

What to take home:
- Patience

Overall impression:
- Lot of scope to improve upon.
- Lot of difficulties in coordinating with several agencies.
- Farmers' participation is not commendable for various obvious reasons.

Ringnodia watershed

Suggestions:
- Follow ridge to valley approach.
- Promote farmers' participation.
- More efforts needed to promote improved crop farm practices.
- Indiscriminate grazing to be stopped by social fencing.
- Promote IPM but recommend chemical pesticides whenever required.
- The animal population is good. Thus there is tremendous scope to promote crop-livestock system.
- One/two team members should stay in the watershed village or within a range of 7–8 km.
- Excavate the big, old water tank.

New things observed:
- IPM is being practiced and farmers are also interested.
- Few good modified gabion structures were observed.

What to take home:
- Nothing specific.

Overall impression:
- Further motivation of farmers and team members is needed.
- Good scope exists for dairying activity.
- There is scope to introduce new farm practices in agriculture.

JNKVV watershed

Suggestions:
- A multidisciplinary team of 8 members is engaged in the on-farm on-station watersheds; one or two members should stay at the on-farm watershed.
- Strategic research should be planned to provide solutions to farmers' problems, e.g., in soybean cultivar JS 335 seed germination in the pods is a problem.
- Proper coordination amongst the team members is needed.

New things observed:

- Nothing specific.

What to take home:

- Nothing specific.

Overall impression:

- Lot of scope to improve on strategic research aspects.
- There is much scope to make the project more farmers' demand driven research project than at present.

IISS watershed

Suggestions:

All the learned scientists working at the station are perhaps already considering the points mentioned below. My intention to mention them again is just to emphasize the significance of these points.

- Strategic on-station research was incorporated in the project to develop and test the technologies/practices based upon the problems/constraints faced by the farmers. In other words these practices must be farmers' demand driven.
- I strongly feel that there should not be duplication of efforts. Review of literature is the first step in deciding the research topic.
- A big and good water tank has been dug on the station. It needs pitching to increase its life.
- A good number of *Gliricidia* plants are planted on bunds. The *Gliricidia* plantation in the field should be more dense than at present.
- The BBF formed at present are along the slope. These can be made across the slope to reduce soil erosion.
- Pisciculture can be introduced in the big tank.

New things observed:

- Good trials of water stagnation effect on soybean.
- Good plantation of *Gliricidia.*
- Hard work and sincere efforts of scientists.

What to take home:

- *Gliricidia* plantation.
- Results of waterlogging.

Overall impression:

A good effort is being made by the scientists. There is good scope also to make it more field-oriented research. This can be achieved by more interaction with the grassroot level workers and farmers.

BW7 watershed

Suggestions:

- A small shift is suggested from basic research to applied research.

New things observed:

- Managing the productivity of soils over 20 years by using appropriate SWNM practices.
- Very good use of *Gliricidia* as green manure.
- IPM.
- Simulation modeling.

What to take home:

- Effective utilization of *Gliricidia.*
- IPM practices.

Overall impression:

- The best on-station watershed.

Adarsha watershed

Suggestions:

- Simplification of gabion structure is needed particularly when a large number of these structures are planned. No frame is required.
- Introduction of horticulture, floriculture, mushroom cultivation, etc., is possible as the farmers are very much motivated.
- Introduce pisciculture in the check dams.
- Promote organic farming/vermi-culture as the farmers have interest.

New things observed:

- Construction of masonary check dam (Bravo!).
- Good planter being used to sow, fertilize, and form the land (Kudos!).
- Vermi-culture being initiated by the farmers.

What to take home:

- Masonary check dam.
- Three-in-one planter.
- Vermi-culture.
- Good cooperation amongst team members.

Overall impression:

- The best on-farm watershed.

General remarks

- Each watershed is unique in itself.
- Each watershed has a different set of advantages, constraints, and limitations.

- The problems also vary to a great extent from one watershed to another.
- The teams working at each watershed are trying their best to develop or implement technologies that suit the needs of the farmers under the available natural resources and constraints/limitations.
- Many suggestions to improve the work at each watershed can be made but these will have to be evaluated for techno-economic feasibility and field practicability before implementation.
- Some common suggestions to be emphasized are:
  - Checking soil erosion with location specific techniques.
  - Conserving maximum rain water and reducing the runoff.
  - Improving land productivity by improved farm practices, SWNM system, and cropping intensity.
  - Strengthening crop-livestock system as farmer has no compartmentalization.
  - Empowerment of the farming community in all above aspects.

All above measures/techniques should be looked into in the context of availability of resources, farmers' perceptions, constraints, and limitations and then should be implemented in a most effective manner.

Feedback on workshop organization

- Excellent effort.
- All arrangements and logistic support were perfect.
- Three-week duration including travel is slightly long for the type of participants involved in the workshop. It could be organized in two modules of 10 days each with a fortnight break in between.
- More frequent interaction between grassroot level workers/farmers and scientists is suggested.
- Instead of grading the watersheds only suggestions to improve would have been more desirable.
- Last but not the least congratulations and thanks for good organization and grand hospitality.

Observations and Suggestions – *K P Raverkar*

Thanh Ha watershed

In a short period of one year appreciable progress has been made in the development of Thanh Ha watershed. Various ways to manage natural resources such as soil, water, and nutrients that are being demonstrated in the watershed are convincing and are being adopted by the farmers in the area.

In the past the cultivation of groundnut was reduced in this area because of pod rotting problem. With the inception of watershed, the cultivation of groundnut is increasing as a variety resistant to pod rot has been introduced under the watershed program. Other interventions such as percolation tanks, staggered trenches, short-duration soybean cultivars, mulching, and *Gliricidia* plantation are showing the visual benefits to farmers. The most important factor for the success of the watershed program is the participation of farmers which can be seen from their interest in new promising technologies and adoption of the demonstrated technologies on their farms. Certain improvements and new initiatives as given below may further show additional impact.

- FYM is perhaps not available in this area locally. Generally it is being imported from other localities which involves cost of transportation. Thus, introduction of green manuring and vermi-composting would help reduce the use of heavy doses of inorganic fertilizers.
- Establishment of grasses in waterways needs attention.
- Intercropping of soybean with maize would prove promising.
- Exposure of farmers to mushroom cultivation using rice straw would give additional income.
- In an experiment on moisture conservation practices in groundnut, observations on biological parameters such as nodulation status and microbial biomass, in addition to other parameters would be handy to explain the results.
- Due to ecological imbalance rat problem is being faced on farms. A preparation with *Gliricidia* heartwood may be evaluated for biological control of rats.

Tad Fa watershed

The watershed concept is not new in this area. The land is given to farmers on tenure basis for cultivation. Generally farmers grow fruit trees on mild slopes instead of on steep slopes and moderate to steep slopes are cultivated. Field operations, even on mild to moderate slopes, are carried out along the slopes. These practices lead to severe soil erosion and degradation. Forest fires pose a great threat to horticultural plantations on steep slopes. *Mimosa* weed which spreads everywhere creates havoc by spreading the fire to cultivated areas.

As seen in the other micro-watershed located nearby agri-horticulture system of cultivation seems to be effective in this area. In the light of the above, to protect and save the natural resources serious efforts should be made to create awareness among the residents about the repercussions of the existing practices as well as to demonstrate the benefits of the new well proven technologies. Some practices are suggested:

- Lands on mild to moderate slopes should be cultivated across the slopes.
- *Gliricidia* plantation on contour bunds will help to reduce soil erosion; the biomass generated can be used as green manure to improve soil fertility.
- Efforts need to be initiated to control the menace of *Mimosa* weed. This will not only ease the field operations but also reduce the chances of spreading the forest fire to cultivated fields.
- Forest fire breaks need to be established before dry season by clearing the few meters of patches between forest and cultivated lands.
- Maize-rice bean relay cropping system seems to be promising. This system needs to be demonstrated on large scale and at multilocations for its adoption by the farmers.
- Establishment of gully plugs and grasses in waterways will reduce soil erosion.
- IPM measures need to be introduced for pest control.
- Water harvesting structures/percolation tanks will prove to be a boon for cultivation of off-season vegetables during dry season.
- Plantation of fruit trees on moderate to steep slopes will check soil erosion.

Ringnodia watershed

The watershed concept in the Ringnodia watershed, Madhya Pradesh, India is quite old. Recently a couple of percolation tanks and a water harvesting tank have been created near the hillocks which is proving quite beneficial in recharging the wells in the area. The short-duration soybean variety Samrat is performing well in the watershed. Pigeonpea has been introduced as an intervention in the micro-watershed. For greater impact of new proven technologies on farmers, the watershed can be improved in multi-angles.

- Farmers' participation in watershed activities can be further improved.
- The common area on hillocks could be considered for hardy horticultural/forest plantations.
- Formation of gullies due to water current can be reduced by "gully plugging" as well as raising grasses in waterways.
- The bunds around the water harvesting tank and other bunds raised are degrading fast. To control degradation of bunds plantation of *Gliricidia* would be effective. Since it is difficult to establish *Gliricidia* due to cattle grazing problem, naturally growing legume weed *Cassia tora* can be exploited.
- The amount of N fixed in biofertilizer trials can be estimated by difference method.
- In Madhya Pradesh, erratic rains sometimes ruin the soybean crop. Therefore, on lands having mild slopes intercropping of soybean with short-duration pigeonpea could prove as an insurance.

JNKVV watershed

The experiments being undertaken in this watershed are maintained neatly. There is a lot of scope to improve the experimentation keeping in view the need of the hour. The organic sources of nutrients should be considered in some experiments. A short-term experiment may be formulated to study the qualitative parameters of vermi-compost prepared from various sources, e.g., weeds, wheat straw, etc., and their impact on soil quality and crop growth.

Lalatora watershed

The Lalatora watershed is coming up very well in the region. Farmers' participation in watershed activities is quite encouraging. Efforts have been made to manage soil, water, and nutrients optimally. However, further improvements are possible.

- Transplantation of *Gliricidia* nursery saplings on bunds would be more successful in comparison to direct seeding.
- Establishment of grasses in waterways will reduce soil loss as well as save the water harvesting structures from silting.
- Some fruit trees can be grown on farm bunds. This may give additional income to farmers.
- Vermi-composting can be exploited as one of the organic sources of nutrients.
- A workable procedure for 'right on water' may be evolved for smooth functioning of watershed and harmony among farmers.
- At village level, a watershed committee/association may be formed for taking decisions in respect of various activities in the watershed.
- Proper equipment for seeding in BBF may be developed/obtained for convenience of farmers.

IISS watershed

Various strategic experiments being conducted are maintained meticulously. The experiment to study the impact of waterlogging on soybean growth and yield is coming up very well; however, certain changes in treatments may have to be made during subsequent years. *Gliricidia* leaf manure farm has come up very well. *Gliricidia* plantation has been done on the bund of water harvesting farm pond. Some of the new initiatives may be taken up as suggested earlier in subsequent years.

Vermi-compost preparation using *Parthenium* weed and other weeds and use of NPV as biological control of pests can be evaluated in strategic experiments.

BW7 watershed

The chain of water harvesting farm ponds is a main feature of the watersheds in ICRISAT. The various water and nutrient budgeting aspects are being handled very meticulously. The range of soil depth in the watershed provides an opportunity to study the impact of soil depth on crop growth. The quality of groundwater is monitored on a regular basis which depicts the impact of fertilizers, chemicals usage, etc., on the groundwater. Vermi-composting using the *Parthenium* weeds and other material is impressive and will prove very handy to cope with the nutrients requirement at low cost in watersheds.

Adarsha watershed

The Adarsha watershed in Kothapally, Andhra Pradesh, India is a model watershed. In this watershed the villagers have formed their own watershed association/committee for monitoring various activities. All farmers carry out the work in the watershed on their own with technical backstopping by ICRISAT and CRIDA. The progress in the watershed is multifarious and appreciable. Farmers are adopting new interventions on their own and managing the watershed as a social affair. The farmers are well aware regarding the organic sources of nutrients such as FYM, vermi-compost, *Gliricidia,* etc. On-farm trials on B and S are coming up well in the watershed. The watershed committee/association is also taking up avenue plantation. Certain initiatives may further improve the watershed impact.

- The training on know-how of mushroom cultivation using rice straw would create an additional avenue of income to farmers.
- *Cassia tora* a leguminous weed is growing in the watershed. It can be evaluated for use as green manure.
- *Bacillus thuringenesis* preparations may be tried as biological control of Lepidopteran pests on cotton.

The comments made are suggestions for improvement and are not meant as criticism.

Evaluation of the Benchmark Watersheds

Summary

The stakeholders of the traveling workshop who are scientists from the international community evaluated the watersheds as a part of the workshop program. Elements of scientific implications, farmers' participation in the implementation of the projects, SWNM options, INM, IPM, and other watershed related data are queried in the questionnaire which was given to individual participants for evaluation of the watersheds. The questionnaire consisted of 25 queries with an objective rating scale of 1–5 where <3 indicates needs improvement; 3– 4 good; and >4 excellent. The participants gave their opinions, ideas, and viewpoints about the eight benchmark watersheds located in India, Thailand, and Vietnam. The questionnaire attempted to identify the appropriate options taken in the benchmark watersheds for sustainable farming systems using a combination of qualitative and quantitative data queries regarding watershed related activities. The specific intention behind these discussions and evaluations was to assess the reasons for change in resource use and to receive information about the scientist's perspective of the future development of farmer's livelihood system in consultation with researchers and farmers. Field level information was mainly assessed through the questionnaires and their analysis resulted in the complete information about all the watersheds.

Human behavior driven by poverty and population dynamics is the underlying cause of land and water degradation. According to the stakeholders, the Thanh Ha watershed, BW7 watershed, and Adarsha watershed were given highest rating in mitigating the adverse effects of drought and drainage and these can prevent land degradation in the respective watersheds as the land and water management research in these watersheds was good whereas the respondents suggested more emphasis in the Tad Fa watershed of Thailand. Overall the watershed development was said to be 'holistic', i.e., the development of common and individual lands were equally treated in all the watersheds which are under study.

Farmers are the ultimate managers of the natural resources and the decision makers in the implementation of watershed related activities. The successful implementation of any activity for sustainable NRM will depend on the extent of farmer's participation. Farmers' participation in the Adarsha and Lalatora watershed activities including construction of water storage structures and field bunds was adjudged as impressive. The scientists suggested that the level of farmers' participation should be improved in the Tad Fa watershed as the involvement of farmers in taking initiatives in any work in this watershed is lacking unlike other watersheds where it was proved to be excellent. The farmers of Tad Fa watershed should be motivated accordingly and involving the local farmers' participation along with adequate professional backup they should satisfactorily address the issues of land degradation and improve their livelihoods.

To derive the impact of management options on soil health and to study the sustainability options detail characterization and monitoring of soil properties over a sufficient period of time and the estimation of changes in production potential are required. The most prominent parameters related to the soil are organic matter content, physical soil structure, soil type, water

retention capacity, and nutrient content. This data would be complemented with climatic data so that the crop production potential could be derived from most important agroecological parameters. The respondents on the whole indicated that the base map of the watersheds is available and topographic features of the land were superimposed in all the watersheds. The collection of various hydrological and soil related data in the watershed and processing was rated as 'Excellent' in the BW7 ICRISAT on-station watershed and Adarsha on-farm watershed. All other watersheds were rated as 'Good'. For this parameter scientists observed that soils in all the watersheds are well characterized and the weather data collection in all the watersheds is exceptionally good.

Soil and water conservation measures are adopted to reduce on-site soil, water, and nutrient losses. These soil and water conservation works undertaken in the on-station BW7 watershed of ICRISAT received appreciation and it was also noted by the participants that in most on-farm watersheds soil and water conservation works are progressing well. However, special emphasis to strengthen this aspect in the Tad Fa watershed was highlighted.

Future strategies for increasing agricultural productivity will have to focus on using available nutrient resources more efficiently, effectively, and sustainably than in the past. Integrated management of the nutrients needed for plant growth, together with effective crop, water, soil and land management will be critical for sustaining agriculture over the long term. INM is an approach that seeks to increase the agricultural production and safeguard the environment for future generations. The INM approach adopted in BW7 watershed got excellent appreciation from the scientists of the workshop; the other watersheds also were graded good in taking up the INM approach. The fertility management strategies adopted in the micro-watersheds were said to be good in all the watersheds studied. The scientists observed that the fertility management outside the micro-watersheds is improving. Further efforts to strengthen technology dissemination were highlighted for Thanh Ha watershed and Tad Fa watershed.

For assessing the impact of watershed technology interventions field level information was also assessed through the questionnaires. The information was generally known about the changes in the cropping systems and can be assessed relatively easily through comparisons of old and new field studies. The long-term data on major crops grown is available for all the watersheds. Suitable cropping systems are evaluated according to the ecoregional potential of the target region in all the watersheds. The new crops and cropping systems introduced, helped the farmers of all the watersheds to increase their farm incomes, to improve their livelihoods and to attain sustainable food production in their respective watersheds. Crop intensification is supplemented with suitable SWNM technologies to prevent further land degradation in all the watersheds studied. The quality of crop management and crop growth in the watershed area was said to be excellent in most of the watersheds but needs little improvement in the Tad Fa watershed.

The respondents opined that Tad Fa watershed, JNKVV watershed, and IISS watershed should use more IPM technology in their watersheds. This will help in controlling diseases, insect pests, and weeds on the farms with the limited resources available.

The expert advice and opinions from the respondents who evaluated the watersheds should be considered by the respondents themselves who are scientists from the watersheds under study.

They should now develop their watersheds in an integrated approach to improve the livelihoods of the poor and solve the problem of land degradation. The integrated approach includes soil conservation (physical and agronomic), water harvesting (terracing and surface dams), irrigation, recycling wastewater, and improved management of organic matter (composting). By combining these activities with environmental monitoring, it is possible to quantify the changes in land use and implementation of improved farming practices. Analysis of the evaluations of the stakeholders is useful to identify the bottlenecks, major activities, and functional areas that need attention and will help the project to do mid-course corrections in the watersheds by integrating the recommendations of the respondents. Current and future needs for increasing the efficiency of the integrated watershed approach can be developed.

Suggestions for individual watersheds

The respondents evaluated each watershed after completion of the 15-day traveling workshop. Taking the respondents as one active group, the overall recommendations of their evaluations for each watershed is given below.

Thanh Ha watershed

- Agave plantations on field bunds to prevent soil erosion.
- Vermi-composting is recommended.
- Crop-livestock system could be evaluated.
- Grassed waterways need to be implemented.
- Loose boulder structures should be constructed for gully stabilization and to act as silt traps.

Tad Fa watershed

- Horticulture and agroforestry should be practiced in the toposequence from hill-valley.
- Soil and water conservation measures need to be strengthened.
- Legumes should be introduced in the cropping system.
- Farmers' participation needs more attention.
- Inter-agencies cooperation needs improvement.
- Land should be cultivated across the slopes.

JNKVV watershed

- Lab to land program should be initiated to make the BBF technology reach the farmers.
- Grassed waterways should be created.
- Vermi-composting should be started.
- IPM practices should be adopted.

Ringnodia watershed

- Legumes should be introduced into the cropping system.
- Gully plugging should be practiced.
- Farmers' participation needs more attention.
- IPM options need to be evaluated.

IISS watershed

- *Gliricidia* should be introduced on the bunds and not on good land.
- Lab to land program should be initiated.
- Waterlogging treatments need to be selected based on the occurrence of natural waterlogging.
- IPM options need to be introduced.

Lalatora watershed

- Loss of nutrients should be monitored.

BW7 watershed

- Nutrient balances (N, P, K, and S) should be estimated separately for flat and BBF landforms.

Adarsha watershed

- Farm income raising programs such as horticulture, floriculture, and mushroom cultivation should be started.
- Agave can be used to stabilize the gullies.

Supporting conclusions

The roots of the problems are now identified in each watershed, and now the immediate action is to solve the problem. Action-oriented approach is now needed by the participants of the workshop. 'Motivational tool' is necessary to achieve the actions from the discussions made. The scientists should now implement the suggestions in their area of operation. The success and effective execution of this workshop will be known only under the strong influence and the efforts of the participants of the workshop in implementing the suggestions and making the 'Integrated Watershed Approach' a big success.

Appendix I

Questionnaire: Evaluation of all watersheds by the participants for various parameters

Sl. no.	Parameter	Thanh Ha (Vietnam)	Tad Fa (Thailand)	JNKVV (Indore, India)	Ringnodia (Indore, India)	IISS (Bhopal, India)	Lalatora (MP, India)	BW7 (ICRISAT, India)	Adarsha (Kothapally, India)
1.	How do you rate the collection of various hydrological and soil related data (both quality and quantity) in the watershed?	3.7	3.4	3.6	3.4	3.6	3.1	4.6	4.0
2.	What is the level of utilization of the natural resources, viz., land and water, that can mitigate the adverse effects of drought and drainage, and prevent further degradation in the watershed?	4.0	2.6	3.3	3.6	3.6	3.7	4.3	4.0
3.	What is the level of farmers' participation particularly in the land and water management area in the watershed?	3.7	2.7	2.0	3.7	2.0	4.4	2.0	4.6
4.	How do you rate land and water management development and research work in the watershed?	3.8	3.0	3.2	3.4	3.4	3.7	4.7	4.3
5.	How do you rate the fertility management strategies adopted in the micro-watershed?	3.5	3.0	3.6	3.6	3.9	3.7	4.4	3.7
6.	Do you think the fertility management followed in the micro-watershed has taken into consideration the integrated approach suitable for local conditions?	3.5	2.9	3.2	3.4	3.2	3.3	4.3	3.9
7.	How do you rate the fertility management outside the micro-watershed but within the bench-mark watershed?	2.5	2.3	3.5	3.2	3.5	3.0	4.0	3.2

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Sl. no.	Parameter	Thanh Ha (Vietnam)	Tad Fa (Thailand)	JNKVV (Indore, India)	Ringnodia (Indore, India)	IISS (Bhopal, India)	Lalatora (MP, India)	BW7 (ICRISAT, India)	Adarsha (Kothapally, India)
8.	How do you rate the probable effects of INM approach on soil quality?	3.3	2.9	3.4	3.3	3.4	3.4	4.3	3.6
9.	How do you rate the present INM approach from economic angle?	3.5	2.9	3.0	3.0	3.0	2.9	3.6	3.3
10.	Is the base map of watershed available and digitized and are the topographic features of the land superimposed on the base map?	3.8	3.7	3.5	3.9	3.3	3.7	4.6	4.6
11.	Are the soils of the watershed characterized for soil physical and chemical properties?	3.8	3.9	4.0	3.9	4.1	3.7	4.7	4.6
12.	Is the weather station at the watershed site installed and functioning? Does the watershed have additional rainguages that are functioning?	4.0	3.6	4.0	4.0	4.1	4.0	4.9	4.3
13.	What is the quality of crop management/crop growth in the watershed area?	4.0	2.9	4.1	3.9	3.9	4.6	4.6	3.9
14.	Are the long-term data on major crops grown available?	3.2	3.0	3.2	3.0	3.3	3.2	4.7	3.3
15.	Are suitable cropping systems (sequential or intercropping) according to the ecoregional potential of the target ecoregion evaluated?	3.5	3.3	3.7	3.7	3.4	3.6	4.0	3.7
16.	Do the new crops and cropping systems help increase farm incomes, improve rural livelihoods, and attain increased and/or sustainable food production?	4.3	3.8	4.0	3.7	4.2	4.1	4.3	4.1
17.	Is crop intensification supplemented with suitable SWNM technologies to prevent further soil degradation?	3.7	3.0	3.7	3.3	3.4	3.7	4.4	4.0

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Sl. no.	Parameter	Thanh Ha (Vietnam)	Tad Fa (Thailand)	JNKVV (Indore, India)	Ringnodia (Indore, India)	IISS (Bhopal, India)	Lalatora (MP, India)	BW7 (ICRISAT, India)	Adarsha (Kothapally, India)
18.	Is the effectiveness of on-farm options of integrated nutrient and water management in farmer participatory mode?	3.8	3.1	3.3	3.6	3.3	3.6	4.3	3.7
19.	How would you rate effectiveness of design and level of management of on-farm watershed trials?	3.8	3.1	3.8	3.4	3.5	3.9	4.8	4..0
20.	Are farmers aware of biological and organic sources of nutrients and are they evaluating/trying these sources?	3.5	2.9	3.0	3.3	3.0	3.6	3.0	3.9
21.	How would you rate farmers' initiatives in the watershed and do you find them involved in the watershed?	3.8	2.9	3.5	3.7	3.5	4.4	3.0	4.7
22.	Is the watershed development holistic, i.e., development of common lands and individual lands treated?	3.7	3.3	4.0	3.4	3.5	3.7	4.7	4.3
23.	Are the baseline data on crop productivity inputs used and constraints to crop productivity identified?	3.5	3.6	3.3	4.0	3.5	3.6	4.7	3.9
24.	How do you rate the soil and water conservation works in the watershed?	3.8	2.9	3.5	3.3	3.3	3.7	4.6	3.9
25.	Are IPM and IDM options included in holistic watershed management approach?	3.2	2.6	2.8	3.3	2.8	3.6	4.0	3.6
	Average	3.6	3.1	3.5	3.5	3.5	3.7	4.4	3.9

Rating scale: 1 = Poor; 2 = Can be improved; 3 = Average; 4 = Good; and 5 = Excellent.

Narration report for each watershed

- For each watershed give your suggestions about what new initiatives can be undertaken or what improvements can be made to the existing things?
- What new things you observed in this watershed?
- What you would like to implement in your watershed after visiting this watershed?
- What is your overall narrative impression about the watershed? Please write in brief.

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Appendix II

Questionnaire: Evaluation of watersheds at different locations by different scientists

Name of the scientist	Thanh Ha (Vietnam)	Tad Fa (Thailand)	JNKVV (Indore, India)	Ringnodia (Indore, India)	IISS (Bhopal, India)	Lalatora (MP, India)	BW7 (ICRISAT, India)	Adarsha (Kothapally, India)
R K Gupta	3.7	3.5	4.2	4.0	3.4	4.1	4.3	4.4
Nguyen Van Viet	4.1	4.0	4.0	4.1	4.1	4.1	5.0	4.0
D Gangadhar Rao	-	3.0	3.9	3.8	3.7	4.0	4.2	4.1
Banyong Toomsaen	3.9	3.6	3.9	4.0	3.9	3.9	4.5	4.1
A B Pande	3.2	2.2	2.6	3.0	2.7	3.2	4.3	3.5
K P Raverkar	3.4	2.0	2.7	2.3	3.4	3.1	4.3	4.0
C Lusanandana	3.5	3.3	3.3	3.4	3.3	3.3	4.1	3.4
Average	3.6	3.1	3.5	3.5	3.5	3.7	4.4	3.9

Rating scale: 1 = Poor; 2 = Can be improved; 3 = Average; 4 = Good; and 5 = Excellent.

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Program

27 August	Delhi/Bangkok–Hanoi, Vietnam
28 August	Inauguration of traveling workshop and visit to VASI
28 August (afternoon)	Travel to watershed site
29 August	Visit to Thanh Ha watershed, Hoa Binh, Vietnam
30 August	Return to Bangkok
31 August	Bangkok–Khon Kaen
01 September	Visit to Tad Fa watershed and strategic research experiment
02 September (afternoon)	Visit to Khon Kaen University
02 September (afternoon)	Leave for Bangkok–Delhi
03 September	Bangkok–Delhi–Indore to visit on-station watershed
04 September	Visit to Ringnodia watershed and travel to Bhopal
05 September	Visit to Lalatora watershed
06 September	Visit to watershed at the Indian Institute of Soil Science, Bhopal
07 September	Bhopal–Hyderabad
08 September	Visit to BW 7 watershed at ICRISAT, Patancheru
09 September	Visit to Adarsha watershed, Kothapally
10–11 September	Report writing
12 September	Participants disburse

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Pictures

Thanh Ha watershed, Vietnam

Tad Fa watershed, Thailand

Micro-watershed at Ringnodia, Madhya Pradesh, India

Watershed at Lalatora, Madhya Pradesh, India

BW7 watershed in Vertic Inceptisols at ICRISAT, Patancheru, India

Adarsha watershed, Kothapally, Andhra Pradesh, India