Global Theme on Agroecosystems
Report no. 13

Baseline Characterization of Benchmark Watersheds in India, Thailand and Vietnam

International Crops Research Institute for the Semi-Arid Tropics

Asian Development Bank

Citation: Wani SP and Shiferaw B (eds.). 2005. Baseline characterization of benchmark watersheds in India, Thailand and Vietnam. Global Theme on Agroecosystems Report no. 13. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 104 pp.

Abstract

The project on "Improving Management of Natural Resources for Sustainable Rainfed Agriculture" (RETA 5812) was executed by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) by adopting a consortium approach for technical backstopping of the community watersheds. The targeted ecoregion is characterized by assured annual rainfall of 700–1300 mm with medium to high water holding capacity soils. Five benchmark watersheds in India, northeast Thailand and northern Vietnam covering the target ecoregion were selected to develop and test the holistic farmer participatory integrated watershed development model with the aim of increasing agricultural productivity on sustainable basis while minimizing land degradation for improving the rural livelihoods. All the five benchmark watersheds in Asia were characterized for socioeconomic parameters by adopting rapid rural appraisals (RRAs) and detailed household surveys using stratified sampling method. The results of biophysical, socioeconomic, characterization as well as inputs and crop productivity are discussed in this report.

This publication is part of the research projects "Improving Management of Natural Resources for Sustainable Rainfed Agriculture" (RETA # 5812) and "Participatory Watershed Management for Reducing Poverty and Land Degradation in the Semi-Arid Tropics" (RETA # 6067) funded by the Asian Development Bank (ADB) to ICRISAT.

Global Theme on Agroecosystems
Report no. 13

Baseline Characterization of Benchmark Watersheds in India, Thailand and Vietnam

Editors

SP Wani and B Shiferaw

ICRISAT
International Crops Research Institute for the Semi-Arid Tropics
Patancheru 502 324, Andhra Pradesh, India

Asian Development Bank
0401 Metro Manila
0980 Manila, The Philippines

2005

About Editors and Authors

SP Wani	Principal Scientist (Watersheds) and Regional Theme Coordinator (Asia), Global Theme on Agroecosystems, ICRISAT, Patancheru 502 324, Andhra Pradesh, India.
B Shiferaw	Scientist (Resource Economics), Global Themes on SAT Futures and Agroecosystems, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India.
Matthew Hughes	9 Lyford Crescent, Forrest Hill, Auckland 10, New Zealand.
Charlotte Donald	9 Lyford Crescent, Forrest Hill, Auckland 10, New Zealand.
TK Sreedevi	Formerly Project Director, Drought Prone Area Program (DPAP), Ranga Reddy District, Government of Andhra Pradesh (AP), Nampally, Hyderabad 500 001, Andhra Pradesh, India. Currently Scientist (Watershed Development), Global Theme on Agroecosystems, ICRISAT, Patancheru 502 324, Andhra Pradesh, India.
K Sailaja	Formerly Consultant, Global Theme on Agroecosystems, ICRISAT, Patancheru 502 324, Andhra Pradesh, India.
PVS Rao	Regional Program Coordinator, BAIF Development Research Foundation, ‘Surabhi’, Lala Lajpatrai Society, E-7/65, Arera Colony, Bhopal 462 016, Madhya Pradesh, India.
AB Pande	Program Coordinator, BAIF Development Research Foundation, ‘Surabhi’, Lala Lajpatrai Society, E-7/65, Arera Colony, Bhopal 462 016, Madhya Pradesh, India.
PK Joshi	Formerly Principal Scientist (Economics), National Centre for Agricultural Economics and Policy Research, New Delhi 110 012, India. Currently South Asia Coordinator, International Food Policy Research Institute (IFPRI), MTI Division, CG Block, NASC Complex, New Delhi 110 012, India.
P Pathak	Principal Scientist (Soil and Water Management), Global Theme on Agroecosystems, ICRISAT, Patancheru 502 324, Andhra Pradesh, India.
GP Saraf	Senior Scienitst (Economics), AICRPDA, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Indore 452 001, Madhya Pradesh, India.
RA Sharma	Principal Scientist/Chief Scientist, AICRPDA, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Indore 452 001, Madhya Pradesh, India.
OP Verma	Dean, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Indore 452 001, Madhya Pradesh, India.

YS Chauhan	Formerly Senior Scientist (Physiology), Global Theme on Agroecosystems, ICRISAT, Patancheru 502 324, Andhra Pradesh, India. Currently working in Farming Systems Institute, PO Box 23, Kingaroy Q 4610, Australia.
Somchai Tongpoonpol	Agricultural Scientist, O/o Agricultural Research and Development, Region 3, 180 Mitra Parb Road, Muang, Khon Kaen, Thailand.
Arun Pongkanchana	Department of Land Development, O/o Agricultural Research and Development, Region 5, Khon Kaen, Thailand.
Pranee Srihaban	Department of Land Development, O/o Agricultural Research and Development, Region 5, Khon Kaen, Thailand.
TJ Rego	Principal Scientist (Soil Science), Global Theme on Agroecosystems, ICRISAT, Patancheru 502 324, Andhra Pradesh, India.
NV Viet	Head, Plant Pathology and Genetics Department, Vietnam Agricultural Science Institute (VASI), Thanh Tri, Hanoi, Vietnam.
HM Tam	Deputy Director, Legume Research and Development Center, Vietnam Agricultural Science Institute (VASI), Thanh Tri, Hanoi, Vietnam.
NT Chinh	Deputy Director, Legume Research and Development Center, Vietnam Agricultural Science Institute (VASI), Thanh Tri, Hanoi, Vietnam.
NV Thang	Head, Groundnut Research Department, Legume Research and Development Center, Vietnam Agricultural Science Institute (VASI), Thanh Tri, Hanoi, Vietnam.
A Ramakrishna	Senior Scientist (Agronomy), Global Theme on Agroecosystems, ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

Acknowledgments

The financial assistance provided by the Asian Development Bank (ADB) through RETA 5812 and 6067 is gratefully acknowledged. The efforts of the consortium team members from Drought Prone Area Program (DPAP); Bhartiya Agro-Industries Foundation (BAIF) Development Research Foundation; Central Research Institute for Dryland Agriculture (CRIDA); MV Foundation of India; Vietnam Agricultural Sciences Institute (VASI), Hanoi, Vietnam; Department of Agriculture (DOA); Department of Land Development (DLD); and Khon Kaen University (KKU), Thailand; are greatly appreciated. At all the benchmark sites, teams of scientists from NARS and ICRISAT are involved in undertaking research; their efforts are also acknowledged. The contributions from Drs. HP Singh (CRIDA), Narongsak Senanarong (DOA), TD Long (VASI), BR Patil (BAIF), are duly acknowledged. The support from ICRISAT staff, Mr Anand Vadivelu and Mr Habeeb; and the secretarial support of Mr KNV Satyanarayana are appreciated. The contribution from farmers is greatly acknowledged; they are important partners who provided necessary information for the project.

Contents

Introduction

This report covers the benchmark socioeconomic surveys conducted at five benchmark locations in three countries (India, Vietnam and Thailand) under the project entitled "Improving Management of Natural Resources for Sustainable Rainfed Agriculture" (RETA # 5812) funded by the Asian Development Bank (ADB), Manila, The Philippines. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India, is the implementing agency for this regional technical assistance project.

Any project/program, whether small or big, far-reaching or limited in scope, regional or national, begins with a needs assessment. Priorities are made and needs are defined by the project leaders. For this to be done, information is needed, which is the basis of all planning; without an appropriate assessment of the prevailing conditions and resources, planning will fail. To have an assessment, data on population, environment, agriculture, industry, the peoples' current economic situation and their needs, characteristics and professional backgrounds, and so forth are needed. Needs assessment is done in all the benchmark sites.

Collection of information

The cycle of planning, monitoring and evaluation begins with a needs assessment and the collection of information relevant to desired goals and indicators to be measured. The information gathered must be applicable to the needs, the reality, the environment, the socioeconomic characteristics and the services already available in an area to build the necessary foundation for the plan. This becomes more important in view of the limited resources.

Many different tools and methods are used for research and data collection. These included questionnaires, interviews, focus group meetings, group discussions, observations, inspection and secondary sources such as reports and documents. Each tool helps in monitoring and evaluating, but it is always good to diversify rather than use only a single tool. The tools have been prepared by the social scientists depending on the project and issues to be evaluated.

The method used here is the Participatory Rural Appraisal (PRA) – an exercise that was carried out by involving the concerned community in defining needs. The PRA gives a quick initial idea. More detailed surveys can be conducted on this basis.

Baseline data survey

At the outset of the project, a baseline survey was carried out to generate the necessary information on the biophysical and socioeconomic environment, context and conditions of the villages and communities. This initial data set builds the basis for subsequent monitoring and evaluation activities. Potential change on the economic, ecological and social system is monitored using the baseline data set. A baseline survey is therefore a precondition in assessing the project impacts and effectiveness.

The baseline survey is the starting and reference point (counterfactual) upon which achievements are judged at any stage of the project process. Baseline surveys are the scientific basis used to assess and measure progress and to assure the availability of qualitative and quantitative data. Baseline data therefore facilitate and/or assist management tasks, including research processes policy and planning decisions. This gives a first insight into the overall biophysical and economic situation of the village or watershed.

In a baseline survey, qualitative and quantitative data were collected. Quantitative data included socioeconomic data on production, yields, population, education and so forth. Qualitative data is not measured in numbers, but in terms of efficiency, satisfaction, effectiveness and other related criteria.

The collected information allows those involved in the project to understand the initial livelihood conditions of the people, and what needs to be done to reach the goal of improving the livelihoods of the poor. This report serves as a reference against which the successes of the project can be measured in the future.

Project goals, purpose, objectives and scope

The objectives of the project are to (1) increase the productivity and sustainability of the medium and high water-holding capacity soils in the intermediate rainfall ecoregion, and (2) develop environment-friendly resource management practices that will conserve soil and water resources. The study is focused on the intermediate rainfall ecozones in central India, northeastern Thailand, and northern Vietnam where the annual rainfall is about 800–1300 mm and where the soils have a relatively high water-holding capacity.

The scope of the project includes benchmark socioeconomic surveys, strategic research, on-farm research and human resource development.

At selected on-farm benchmark watershed sites (three in India, one each in Thailand and Vietnam), detailed socioeconomic surveys, PRAs and rapid rural appraisal (RRA) techniques were used for studying major socioeconomic, biotic, and abiotic constraints to sustainable crop production. Based on the PRA and RRA studies conducted, the constraints and general findings were reported in the first annual report submitted covering the period of January–December 1999.

Partnerships

The participating developing member countries (DMCs) of the project are India, Thailand and Vietnam. Our partners for carrying forward the research and development agenda of the project are as follows:

International institution

- Management of Soil Erosion Consortium (MSEC) project, International Board for Soil Research and Management (IBSRAM), Thailand.

Developing member country institutions

India

- Central Research Institute for Dryland Agriculture (CRIDA), Indian Council of Agricultural Research (ICAR), Santoshnagar, Hyderabad.
- Indian Institute of Soil Science (IISS), ICAR, Bhopal, Madhya Pradesh.
- Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Indore, Madhya Pradesh.
- National Remote Sensing Agency (NRSA), Hyderabad, India.
- Drought Prone Area Program (DPAP), Government of Andhra Pradesh.
- Bhartiya Agro-Industries Foundation (BAIF) Development Research Foundation, Bhopal, Madhya Pradesh (non-governmental organization).
- M Venkatarangaiah Foundation (MVF), Hyderabad, Andhra Pradesh (non-governmental organization).

Thailand

- Royal Department of Agriculture (DOA), Bangkok
- Royal Department of Land Development (DLD), Bangkok
- Khon Kaen University (KKU), Khon Kaen, Thailand

Vietnam

- Vietnam Agricultural Science Institute (VASI), Hanoi

Advanced research institutions

- Michigan State University (MSU), East Lansing, MI 48824-1325, USA
- University of Georgia, Griffin, Georgia 30223-1797, USA

Adarsha Watershed, Kothapally, Andhra Pradesh, India

Matthew Hughes, Charlotte Donald, SP Wani, TK Sreedevi and K Sailaja

Location

Andhra Pradesh (AP) is the fifth largest state in India, in terms of both area and population, bounded by Madhya Pradesh and Orissa in the north, the Bay of Bengal in the east, Tamil Nadu and Karnataka in the south, and Maharashtra in the west. Andhra Pradesh forms the major link between north and south of India. The population of the state is 7.57 million according to the 2001 census and the sex ratio is 977 females per 1000 males, which is higher than the country's average of 929. The literacy rate of the country is 35.74% – AP is ranked 25th among the 35 states and union territories. The literacy rate among males is 47.28% and among females is 23.92% (NCAER 2001). The per capita state domestic product in 1990–91 at 2001 prices was Rs. 5215 (Shiv Kumar 1991). The climate is hot and humid with an average rainfall of 925 mm. The state of AP consists of 23 districts: (1) Andhra, the coastal region is made up of nine districts; (2) Rayalaseema, the interior region consisting of four districts; and (3) Telangana region consisting of the state capital, Hyderabad, and nine adjoining districts. The Telangana zone comprises 42% of the state and lags behind the other two regions in terms of socioeconomic and demographic indicators. One of the benchmark sites, Adarsha Watershed in Kothapally village, is located at Shankarpally mandal, Ranga Reddy district, in Telangana region of Andhra Pradesh, India (Figure 1). The Kothapally village was selected after visiting and inetracting with farmers in three villages (Appendix 1).

The village Kothapally is situated 50 km from Hyderabad, the state capital of Andhra Pradesh. The closest markets are the towns of Chevalla and Shankarpally, located about 20 km away from the watershed. The population of the village is 1492 with 274 households. The total land area is 464 ha, with an average landholding per household of 1.7 ha. The Kothapally watershed is characterized by undulating topography and black soils.

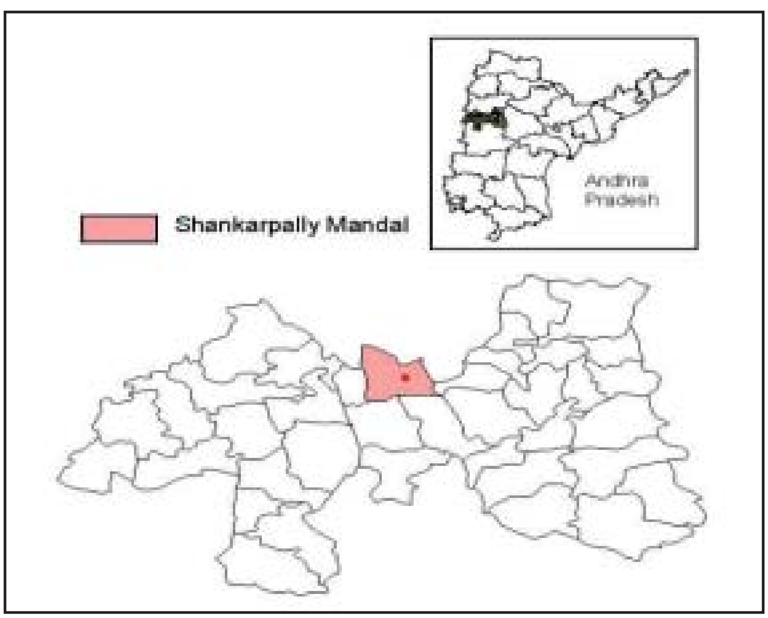


Figure 1. Location of Kothapally village in Shankarpally Mandal, Ranga Reddy district, Andhra Pradesh.

Micro-watershed

For detailed hydrological and productivity measurements, a 30 ha micro-watershed based on the topographic survey was delineated. In this micro-watershed, the effect of soil and water conservation measures on runoff, soil loss, agricultural productivity and soil quality was studied. Figure 2 shows the location of the micro-watershed within the Adarsha Watershed.

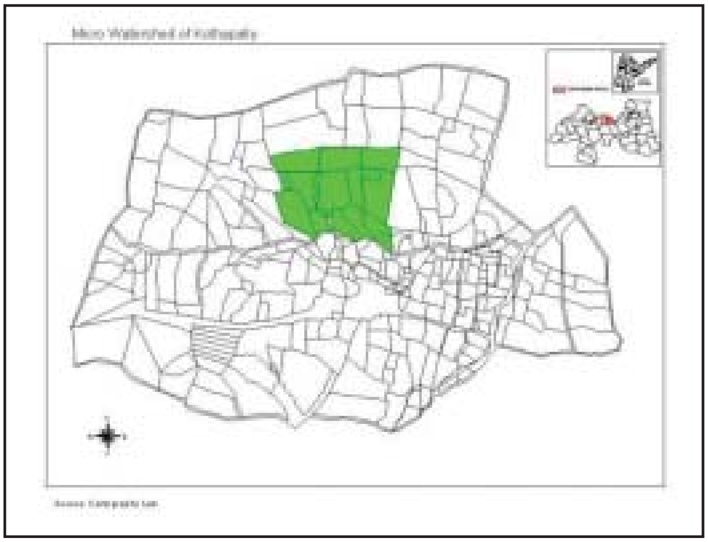


Figure 2. Designated micro-watershed in Kothapally village.

Methodology

Two hundred and seventy four households in the village were divided based on their landhodling size and the households were classified into three groups: small (less than 1 ha [excluding landless]), medium (1 to 2 ha) and large landholders (greater than 2 ha). The small landholders, medium landholders and large landholders constituted 50% (137), 22% (60) and 27% (73) of the households, respectively.

Twenty percent of the households were selected for a detailed survey. Accordingly, fifty-five families from different landholding classes were selected proportionately. Out of a total 274 households, four (1%) were landless in the village. The 20% proportional sample constituted 28 small landholders, 12 medium landholders and 15 large landholders. In addition, 18 households who had land in the micro-watershed were also selected for a detailed survey. The households from each landholding group were selected randomly using random number tables. In total, 73 families were surveyed in detail using structured questionnaires (Appendix 2). The data collection was completed within 3 months.

Social structure and land tenure

Distribution of land and landholdings

In Adarsha Watershed at Kothapally, large landholders (greater than 2 ha land) who were about 27 percent of the total population possessed 69 percent of the farmland with an average landholding of 4.29 ha. Medium landholders (1 to 2 ha) who were about 22 percent of the total population held 16 percent of the farmland with an average landholding of 1.25 ha. On the contrary, small landholders (less than 1 ha) who constituted 50 percent of the households held 15 percent of the farmland with an average landholding of 0.525 ha (Table 1).

Table 1. Landholdings of small, medium and large landholders in Kothapally.

Landholders	No. of households	Total land area(ha)	Average landholdings(ha)
Small (<1.0 ha)	136 (50)*	71.40 (15)	0.52
Medium (1.0–2.0 ha)	60 (22)	75.30 (16)	1.25
Large (>2.0 ha)	74 (27)	317.60 (69)	4.29
Total	270	464.30	1.72

* Values in parenthesis indicate percentages.

Family composition

In Kothapally, the average family size was seven consisting of four males and three females (Figure 3). With regard to age structure (Figure 4), the family consisted of one child (up to 5 years), two young adults (6–18 years) and four adults (19–55 years) in the village.

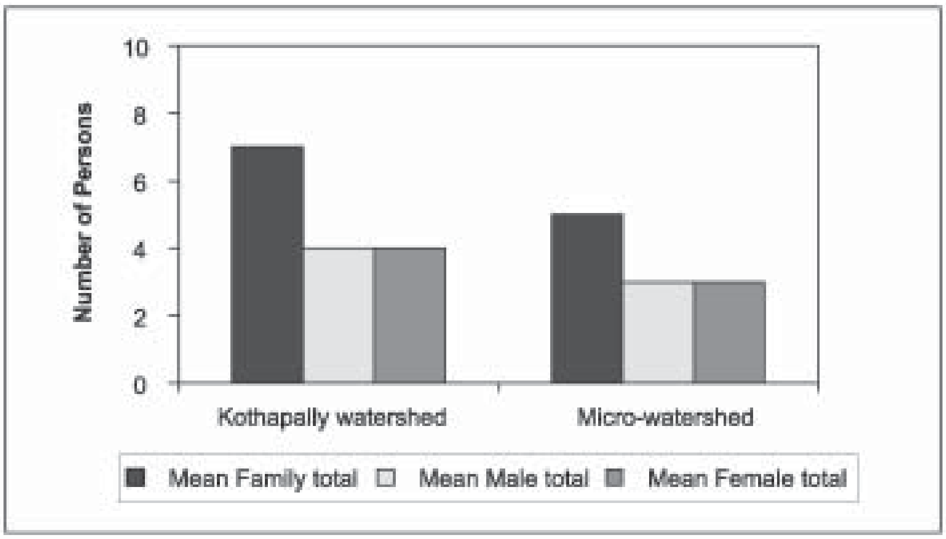


Figure 3. Family composition in Kothapally village.

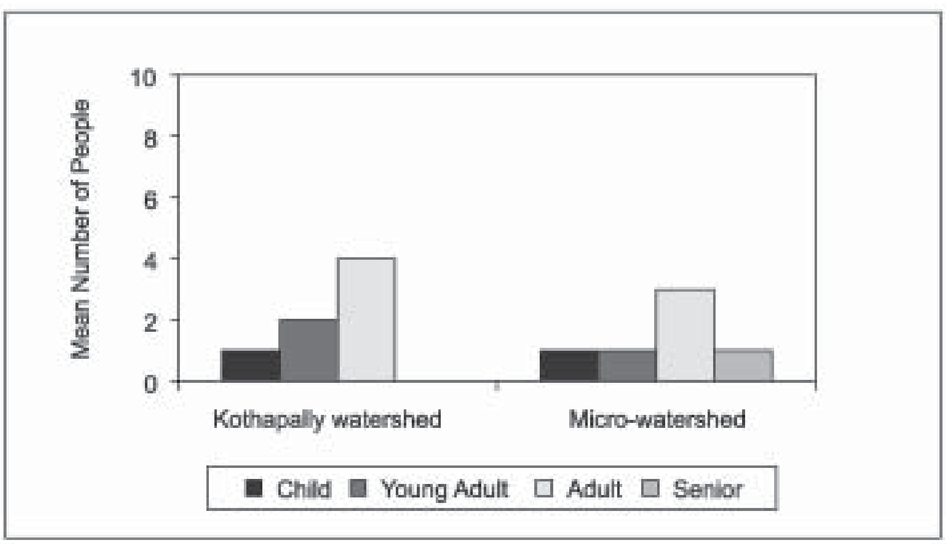


Figure 4. Age structure in Kothapally village.

Social strata

With a total village population of 1492, 54% of the population belongs to backward communities (BC), 15% to minority community (Muslims), 20% to scheduled castes (SC) and 9% to other castes as shown in Table 2 (Figure 5). It needs to be noted that only landholders were surveyed, and while these figures should be a fair representation of those who possessed land, the data did not include landless households.

Table 2. Caste wise distribution of farm households in Adarsha Watershed.

Category	ST	SC	BC	Minorities	OC	Total
< 1.00 ha(Small landholders)	4 (3)	20 (15)	64 (47)	17 (12)	31 (22)	136
1.00–2.00 ha(Medium landholders)	-	8 (13)	38 (63)	5 (8)	9 (15)	60
> 2.00 ha(Large landholders)	-	7 (10)	35 (47)	6 (8)	26 (35)	74
Total	4 (2)	35 (13)	137 (51)	28 (10)	66 (24)	270

Note: ST = Scheduled tribe, SC = Scheduled caste, BC = Backward caste, OC = Other caste.Values in parenthesis indicate percentages.

Caste and education

Education levels are discussed here across castes as caste plays an important role in the level of education of a person in India. Over 80 percent of the scheduled castes (SC) in Kothapally had no school education, while 10 percent of them had been to elementary school, and another 10 percent had been to high school. Nearly 70 percent of the backward castes (BCs) had no school education, and almost 20 percent had been to elementary school. Ten percent of the BCs had been to high school and less than 5 percent had been to college. Sixty percent of the other castes had no schooling, while the rest 40 percent had been to elementary school. Over 60 percent of the Muslims had no school education, and 25 percent of them had been to high school. Some 13 percent of the Muslims had been to a tertiary institute (no formal education).

Beteille (1974) stated that literacy and education might be unevenly distributed in an agrarian society and the data collected in Kothapally supported this statement with regards to inequalities between sexes and between castes. The above data revealed that the education level increased along the caste hierarchy. This pattern was seen throughout India, which highlighted the fact that educational

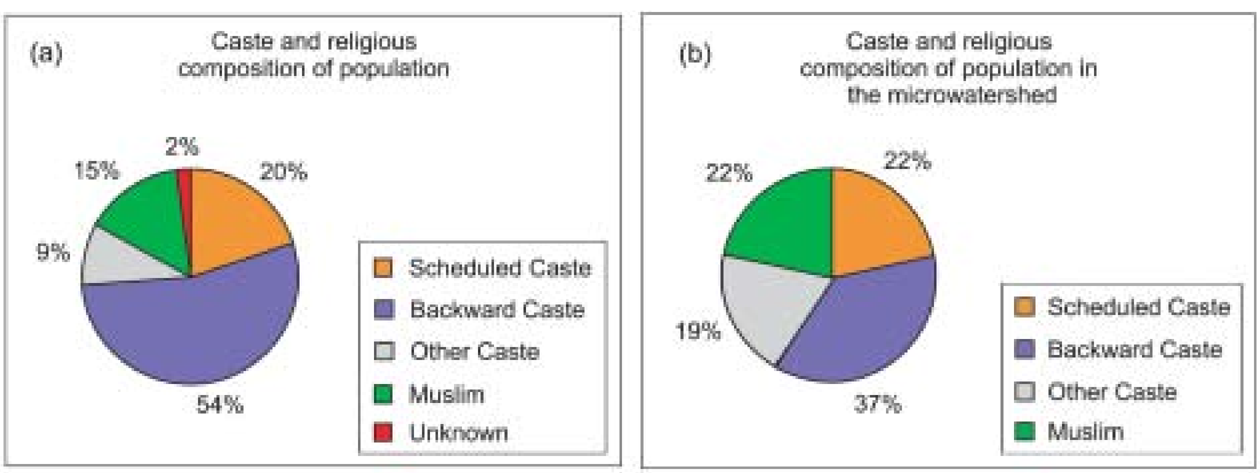


Figure 5. Caste and religious composition of (a) Kothapally watershed and (b) micro-watershed.

opportunities were traditionally been taken up by higher castes. M. Venkatarangaiah Foundation (MVF), the NGO in Kothapally Village, is trying to address this situation through an intensive program to abolish child labor and child marriages, and to provide educational opportunities for lower castes. MVF's presence in Kothapally seems to have contributed to increased child enrollment in local schools, especially preventing the children being taken out of school for domestic and field works by the lower castes. It would take some time for the educational patterns to change in Kothapally, and it remains to be seen whether exposure to basic education prompts the lower castes to continue high school and college studies.

Gender and education

Education levels were also studied in terms of gender as it is a known fact in India that gender always played a major role in the level of education a person attains traditionally. Females are traditionally neglected and are not encouraged to go to schools. Rather they are sent for work to earn money for the family. This fact was evident in Kothapally village. Nearly 40% of males in the village received some form of education, while less than 10% of females had been to school. The discrepancy between the sexes was striking, with males having received some form of education when compared with females. A major part of MVF's programs was focused on the girl-child by providing opportunities to attend schools and breaking the cycle of illiteracy that is perpetuated from generation to generation. Girls' education is key to women's empowerment.

Education levels within family

On an average, there were three people per family in Kothapally without any form of educational background, one child per family at preschool, two young people at elementary school and one family member at high school (Figure 6).

Caste and land tenure

The BCs were the dominant landowners in Adarsha Watershed, Kothapally, with the OCs owning relatively small percentages of the small and medium landholdings. This finding supported other

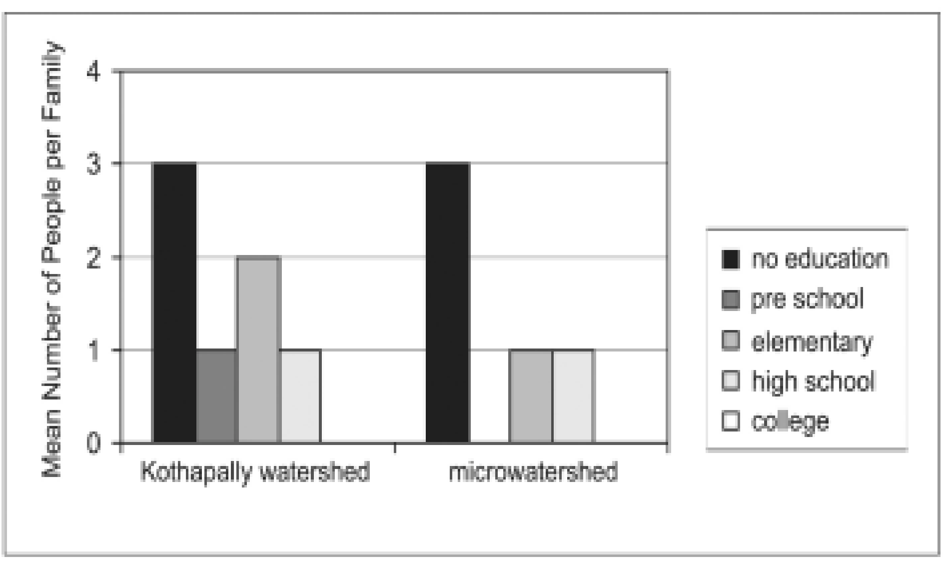


Figure 6. Education levels at Kothapally village.

studies, which showed that at the local level the dominant landowning group often was at the middle and not at the top of the caste hierarchy (Beteille 1974).

The backward castes constituted 47 percent of the small landholders and held 51 percent of the total land held by the small landholders. The scheduled castes (SCs) constituted 15 percent of the small landholders and held 13 percent of the land held by the small landholders (Tables 2 and 3). The OCs constituted 22 percent of the small landholders and held 20 percent of the land held by the small landholders (Tables 2 and 3). Among the medium landholders, BCs comprised 63 percent and held 65 percent of the total land held by the medium landholders. SCs constituted 13 percent of the total medium landholders and held 13 percent of landholdings. Amongst the large landholders, BCs comprised 47 percent of the landholders and held 37 percent of the land held by the large landholders. The OCs comprised 35 percent of the large landholders and held 51 percent of the total land held by the large landholders. Mean land held across the landholding groups was least at 0.44 ha per household for STs followed by 1.1 ha for SCs, 1.15 by minority communities, 1.49 ha by BCs and 2.85 ha by OCs (Table 4). Amongst the large landholders, OCs held 7.24 ha per household as against 2.74 to 3.39 ha by SCs, minorities and BCs. Amongst the medium and small landholders, land held by BCs, SCs and minorities is of a similar magnitude as that of the land held by OCs (Table 4).

Gender and land tenure

Landholders were dominantly male; 80% of the land in Kothapally village and 85% of the land in the micro-watershed area was owned by males. The land owned by female-headed households mainly comprised widowed women whose sons had not attained majority. Daughters could claim the land when it was included in the dowry, but then this became the property of her husband and his family. The dominance of males in terms of land ownership, combined with higher educational attainment indicated that the balance of power was strongly weighted in favor of males.

Table 3. Caste wise landholding (ha) in Adarsha Watershed.

Land (ha)	ST	SC	BC	Minorities	OC	Total
<1.00	1.76 (2.5)*	9.67 (13)	36.33 (51)	9.35 (13)	14.30 (20)	71.41
1.00-2.00	-	9.56 (13)	48.72 (65)	6.18 (8)	10.83 (14)	75.29
>2.00	-	19.19 (6)	118.63 (37)	16.62 (5)	163.14 (51)	317.58
Total	1.76	38.42 (8)	203.68 (43)	32.15 (7)	188.27 (41)	464.28

* Values in parenthesis indicate percentages.

Table 4. Average landholding (ha) per household in different landholding sizes and caste distribution.

Landholdings	ST	SC	BC	Minorities	OC	Total
Small (< 1 ha)	0.44	0.48	0.56	0.55	0.46	0.52
Medium (>1–2 ha)	-	1.2	1.28	1.24	1.2	1.25
Large (> 2 ha)	-	2.74	3.39	2.77	7.24	4.29
Total	0.44	1.1	1.49	1.15	2.85	1.72

Agriculture – Land Use and Crop Production

Irrigation

The irrigated area consisted of 20% of the total area for small landholders, while it was only 10% in the case of medium landholders. The large farmers had a higher percentage (40%) of the owned area.

The micro-watershed showed a different pattern of irrigation. Only 10% of the small landholders had irrigated crops, while more than 30% of medium landholders had irrigation facility. Large landholders in the micro-watershed had no irrigation at all (Figure 7).

Cropping pattern in the 1998 rainy season *(kharif)*

The major sole crops grown were paddy and cotton, and intercrops grown were sorghum/ pigeonpea. Paddy being the staple food crop occupied 41.65 ha (22.50% of the cultivated land). The next major crop in terms of acreage was cotton which was cultivated in medium black to deep black soils in 33 ha (17.83% of the land). Cotton is an important cash crop which is grown in black soils ranging from soil depths greater than 90 cm. Black soils with high clay content provided a suitable physical environment for greater moisture retention and less percolation losses. Among intercrops, sorghum/pigeonpea occupied 21.34 ha (11.53%) of the area. A large diversity in the cropping pattern in mixing various combinations of crops is shown in Table 5. Fallow/waste land constituted 11.83% of the area. Figure 8 shows the cropping pattern during the rainy season in 1998.

Cropping system – 1998 postrainy season crop *(rabi)*

The major crops grown during *rabi* season on residual soil moisture or with irrigation were vegetables and chickpea. Vegetables were cultivated in deep black soil of greater depth than 90 cm in an area of

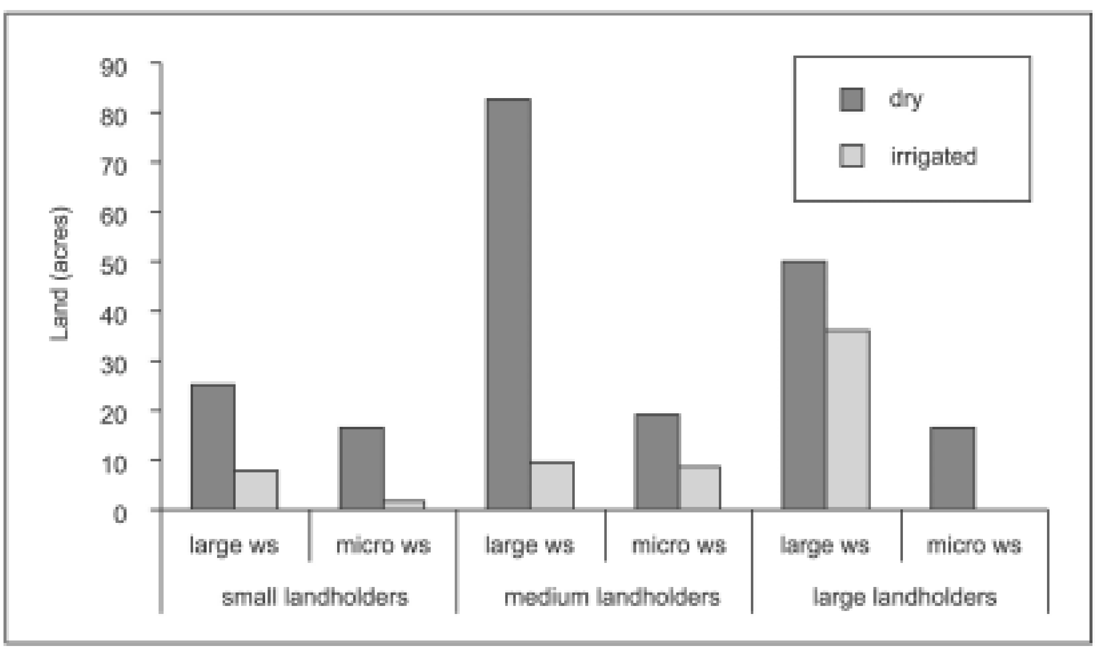


Figure 7. Land use (dry or irrigated) by small, medium and large landholders of Kothapally village.

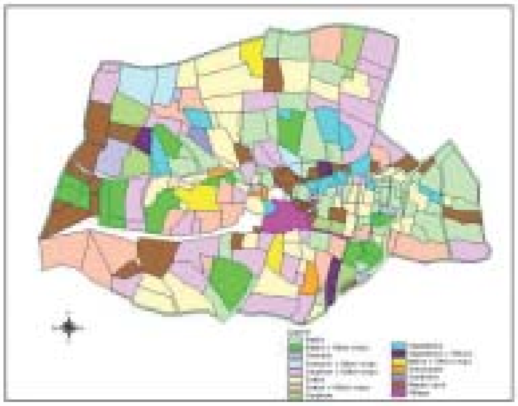


Figure 8. Cropping pattern, rainy season 1998.

Table 5. Diversity of crops grown in Adarsha Watershed, Kothapally, rainy season, 1998.

Cropping system	Total area in ha	Percentage
Sorghum/pigeonpea + beans	0.06	0.03
Sorghum/pigeonpea + cotton + turmeric	0.08	0.04
Paddy + tomato	0.08	0.04
Sorghum + turmeric + paddy	0.10	0.05
Sorghum/pigeonpea + turmeric	0.16	0.09
Sorghum/pigeonpea + green gram	0.26	0.14
Beans + fallow	0.29	0.16
Paddy + chickpea	0.34	0.18
Government land	0.43	0.24
Turmeric + cotton + paddy	0.49	0.26
Cotton + flowers	0.50	0.27
Cotton/sorghum + turmeric	0.52	0.28
Sorghum + beans + cotton	0.55	0.30
Cotton + beans + sorghum/pigeonpea	0.59	0.32
Green gram/cotton + beans	0.60	0.32
Maize/pigeonpea	0.60	0.32
Maize/cotton	0.79	0.43
Maize + wasteland	0.98	0.53
Vegetables	1.04	0.56
Green gram	2.06	1.11
Sunflower	2.28	1.23
Paddy + turmeric	2.38	1.29
Turmeric + beans + paddy	2.95	1.59
Cotton + sorghum	3.33	1.80
Cotton + beans	3.93	2.12
Turmeric	4.23	2.29
Cotton + paddy	4.36	2.36
Paddy + sorghum/pigeonpea	4.39	2.37
Sorghum	8.91	4.85
Beans	8.97	4.81
Sorghum/pigeonpea + cotton	10.96	5.92
Sorghum/pigeonpea	21.34	11.53
Waste/fallow	21.89	11.83
Cotton	33.00	17.83
Paddy	41.65	22.50
Total	185.10	100.00

14.84 ha (15.33%) followed by chickpea in medium black to deep black soils in an area of 28.7 ha (29.65%) and in a few pockets of *Choudu* soils, where the soil depth was up to 50 cm. The analysis revealed that the cropping pattern in *rabi* was determined by the availability of residual soil moisture or irrigation facility as shown in Table 6. Figure 9 shows the postrainy season cropping pattern in Adarsha Watershed in 1998.

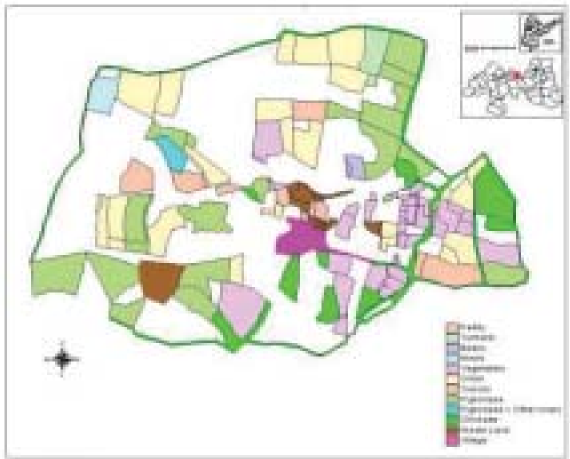


Figure 9. Postrainy season cropping pattern during 1998–1999.

Table 6. Crops grown in Adarsha Watershed, Kothapally, postrainy season, 1998–99.

Cropping system	Total area (ha)	Percentage
Onion + beans	0.28	0.29
Paddy	0.72	0.74
Onion + chickpea	1.19	1.23
Pigeonpea	1.20	1.24
Onion + chickpea + vegetables	1.25	1.29
Tomato + chillies	1.38	1.43
Beans	1.54	1.59
Vegetables + chickpea	1.58	1.63
Onion + chillies	1.71	1.77
Waste/fallow land	1.76	1.82
Pigeonpea + vegetables	3.02	3.12
Onion + chickpea + tomato	3.23	3.34
Chillies	3.29	3.40
Onion + tomato	3.41	3.52
Tomato	3.71	3.83
Turmeric	4.39	4.54
Onion + vegetables	5.56	5.74
Chickpea	5.98	6.18
Onion	8.04	8.31
Vegetables	14.84	15.33
Chickpea	28.70	29.65
Total	96.78	100.00

Figure 10 illustrates the season-wise cropping pattern of small, medium and large landholders. Majority of small, medium and large landholders (31 percent, 43 percent and 16 percent,

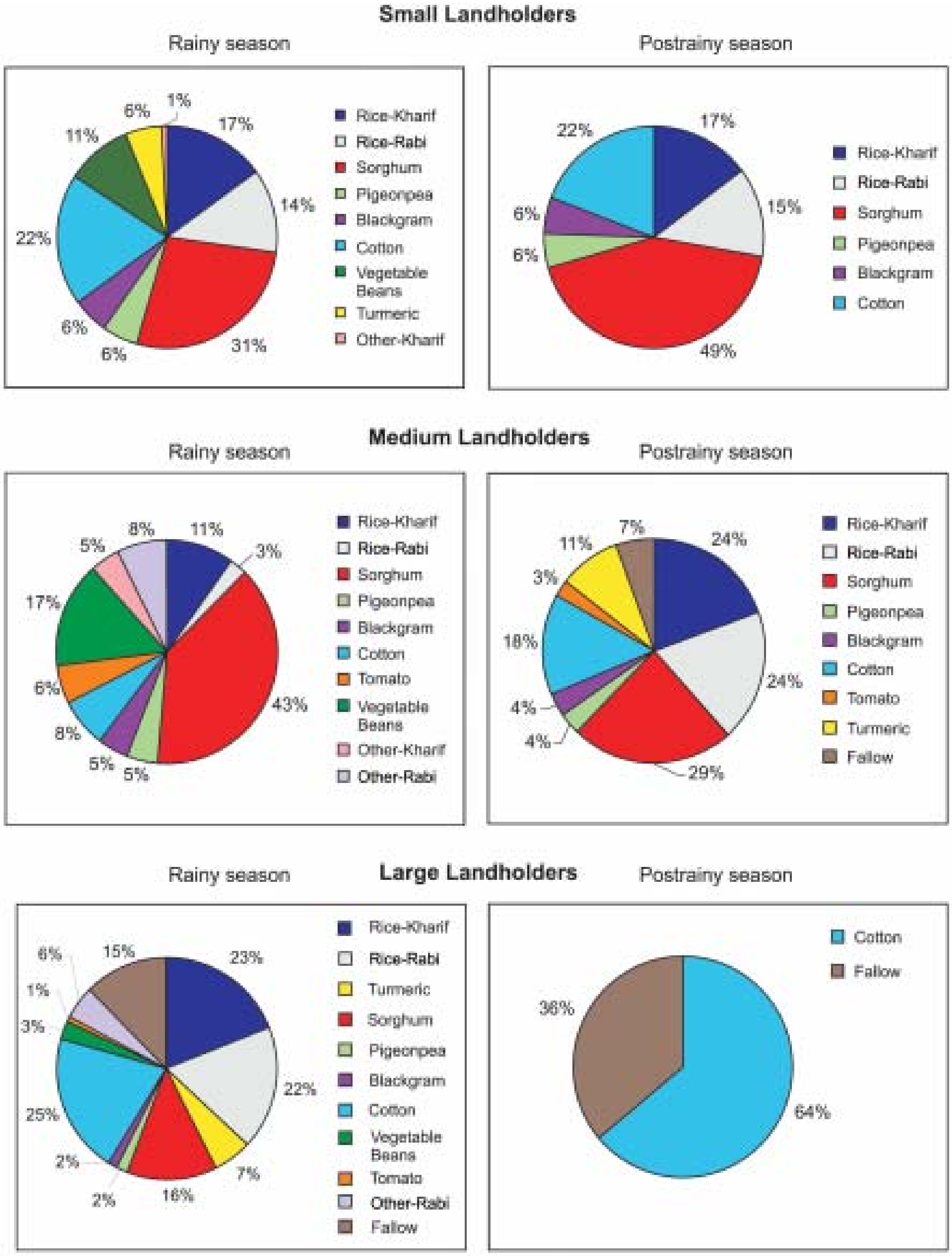


Figure 10. Cropping pattern of small, medium and large landholders in rainy and postrainy seasons at Kothapally watershed.

respectively) grew sorghum crop during the rainy season. Rice (*kharif*), sorghum and pigeonpea were the major crops among the large landholders and sorghum crop was the major crop for small and medium landholders.

Landholding

The average landholding of 73 surveyed farmers was 2.34 ha with 0.41 ha of irrigated and 1.93 ha of dry land.

Soils

The soil types ranged between shallow black soils (less than 50 cm), medium black soils (50 to 90 cm), deep black soils (greater than 90 cm), red soils (less than 50 cm) and sodic soils (less than 50 cm). Figures 11 and 12 show the soil types – the deep black soils are more fertile with greater clay content and greater moisture retention. Medium-to-deep black soils in the postrainy season had high productivity where crops were taken up on residual moisture.

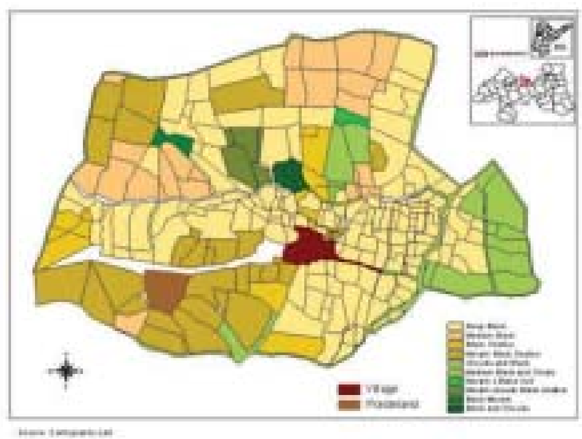


Figure 11. Soil Types in Adarsha Watershed, Kothapally village.

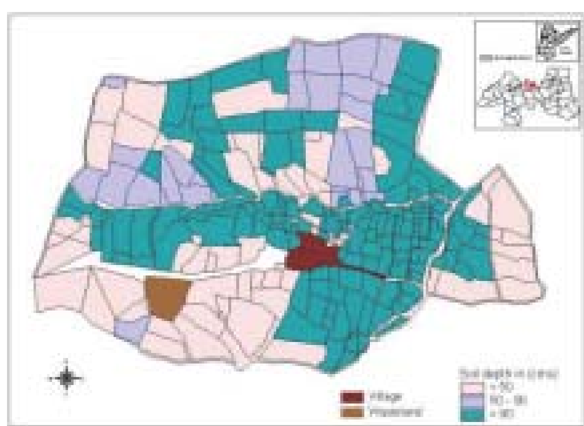


Figure 12. Soil Depth profile in Adarsha Watershed, Kothapally village.

Groundwater level

The average depth of the 56 wells surveyed is 7.35 meters. The groundwater levels showed a high degree of variability with depths ranging from 2 meters to 18.65 meters, as shown in Table 7. The variation in the groundwater depth and the amount of water harvested is based on the cropping pattern and other factors such as soil type, crops grown, topography (relief), runoff and geological factors of the area.

Table 7. Location of the wells and groundwater level in Kothapally village in 1998.

Well ID	Latitude	Longitude	Groundwater level (m)
1	17.625	78.170	7.9
2	17.6244	78.1763	7.5
3	17.6244	78.1766	6.0
4	17.6244	78.1769	6.2
5	17.6302	78.1797	6.0
6	17.6280	78.1800	4.0
7	17.6280	78.1819	4.0
8	17.6247	78.1836	4.1
9	17.6266	78.1850	5.4
10	17.6266	78.1855	9.6
11	17.6261	78.1872	5.5
12	17.6266	78.1877	7.2
13	17.6297	78.1869	7.0
14	17.6302	78.1875	8.0
15	17.6308	78.1838	7.6
16	17.6308	78.1905	7.0
17	17.6311	78.1905	8.0
18	17.6394	78.1766	12.0
19	17.6391	17.6333	10.0
20	17.6402	78.1808	9.0
21	17.6397	78.1822	11.4
22	17.6333	78.1827	10.2
23	-	-	8.0
24	17.6341	78.1883	9.1
25	17.6411	78.1936	10.6
26	17.6416	78.1966	8.0
27	17.6405	78.1966	12.0
28	17.6430	78.1986	12.0
29	17.6463	78.2016	11.0
30	17.6469	78.2044	8.7
31	17.6155	78.1908	3.6
32	17.6155	78.1911	2.0
33	17.6166	78.1975	8.0
34	17.6163	78.1991	5.2
35	17.6161	78.2008	4.0
36	17.6208	78.2077	6.0
37	17.6241	78.2141	7.0
38	17.6244	78.2144	5.7
39	17.6291	78.2211	7.4
40	17.6325	78.2180	6.0

... Continued

Table 7. ***Continued...***

Well ID	Latitude	Longitude	Groundwater level (m)
41	17.6305	78.2161	7.0
42	17.6300	78.2158	8.0
43	17.6313	78.2122	3.2
44	17.6275	78.2111	3.7
45	17.6311	78.2063	6.8
46	17.6286	78.2058	6.6
47	17.6272	78.2030	5.0
48	17.6330	78.2022	6.2
49	17.6336	78.2036	7.0
50	17.6363	78.1997	18.6
51	17.6338	78.1988	9.5
52	17.6327	78.2002	6.0
53	17.6347	78.1977	9.3
54	17.6305	78.1977	6.0
55	17.6297	78.1966	2.5
56	17.6269	78.1968	7.6
Average			7.3

Productivity within land sizes

The productivity for each crop within small, medium and large landholders has been tabulated in Table 8. The sample sizes for small, medium and large landholders were 27, 22 and 5 farmers, respectively.

Crop productivity in Kothapally village

The analysis of Table 8 revealed that the productivity of rice ranged between 266.7 kg ha^{-1} and 2400 kg ha^{-1} for small landholders, while conversely the large landholders had a much lower range of 187.8 kg ha^{-1} to 941.2 kg ha^{-1}. The average productivities in small, medium and large landholders were 2830 kg ha^{-1}, 3090 kg ha^{-1} and 1660 kg ha^{-1}, respectively. A similar trend was also observed in the case of pulse crops. In the case of cash crops, the productivity of cotton among small landholders ranged between 380.95 kg ha^{-1} to 1384.6 kg ha^{-1} with an average of 210 kg ha^{-1}. Among medium landholders, it ranged between 333.3 kg ha^{-1} to 977.8 kg ha^{-1} with an average of 1430 kg ha^{-1} and in large landholders the range was 170.9 kg ha^{-1} to 520.8 kg ha^{-1} with an average of 670 kg ha^{-1}. In medium landholders, the turmeric crop recorded a highest productivity of 11,000 kg ha^{-1} whereas 842.5 kg ha^{-1} and 495.5 kg ha^{-1} of turmeric productivity was recorded in the case of small and large landholders, respectively. In vegetable crops such as beans and tomato, small and medium landholders recorded highest productivity means (551 kg ha^{-1} to 327.8 kg ha^{-1}), respectively.

Table 8. Crop productivities (t ha^{-1}) in Kothapally village.

Land-holders	Rice	Turmeric	Sorghum	Pigeonpea	Black Gram	Cotton	Beans	Tomato	Other Crop
Small	2.83	2.10	1.47	0.19	0.83	0.21	0.79	–	0.33
Medium	3.09	2.75	1.19	0.15	0.57	1.43	1.37	0.81	0.74
Large	1.66	1.23	0.54	0.13	0.25	0.67	0.19	0.75	1.33

Inputs

DAP and urea

The majority of farmers used DAP and urea fertilizers. The amount of DAP (Figure 13a) and the urea (Figure 13b) applied per hectare fell sharply as the farm size increased.

Potash and super phosphate

The nutrients were only applied to paddy. The amount of potash (Figure 13c) and super phosphate (Figure 13d) applied declined with the increasing land size. In general, within Adarsha Watershed, there was a rapid decline in applied amounts, with small increases in landholdings of about 1–2 ha. As the land size increased in Kothapally Watershed, the amount of treatment per hectare remained between 15 and 75 kg. Within the micro-watershed, three farmers who were using potash and super phosphate indicated a decline in application per hectare with the increase in farm size (Figure 13).

Farmyard manure and compost

The two inputs – farmyard manure (FYM) and compost – showed a variation in the level of utilization among farmers. In the Adarsha Watershed, Kothapally, there was a general decline in the amount of FYM (Figure 13e) applied per hectare within the small landholdings. The most significant anomaly was application of nearly 6250 kg ha^{-1} of FYM in a plot of about 5 ha. Another slight variation in this trend occured for a plot of about 10 ha where approximately 1250 kg ha^{-1} was applied. Compost used showed a decline similar to that of fertilizer with increase in cultivated land (farm size) (Figure 13e).

Weedicides and insecticides

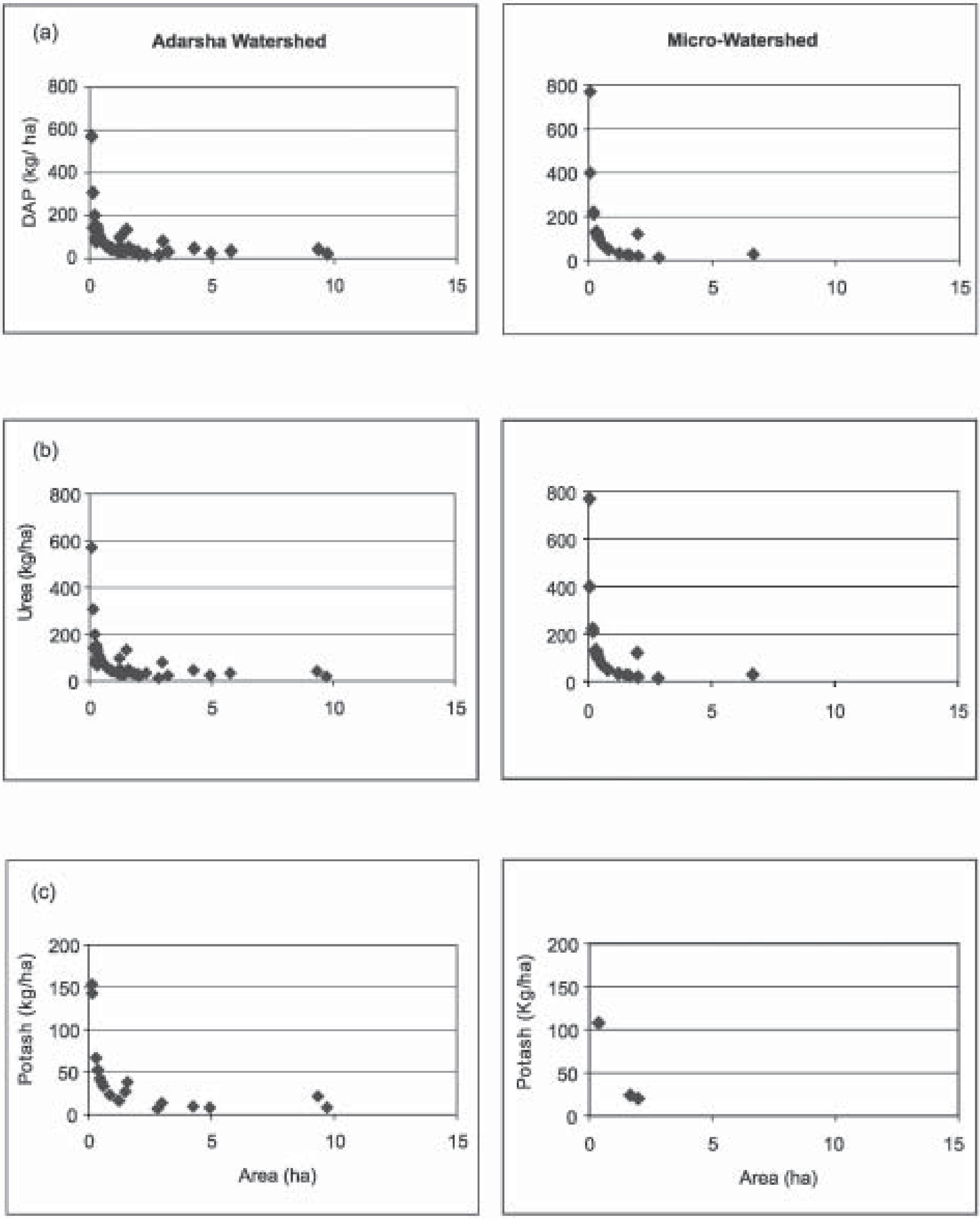
Within the Kothapally Watershed, weedicides (Figure 13f) and insecticides (Figure 13g) were applied in varying amounts amongst the small landholdings. Overall, a general decline in the use of weedicides and insecticides was noted in Adarsha Watershed and micro-watershed with the increased landholding. The micro-watershed showed a sharp drop in weedicides and pesticides in the case of farmers owning up to one acre, and a gradual decline with increasing land size.

Caste and livestock possession

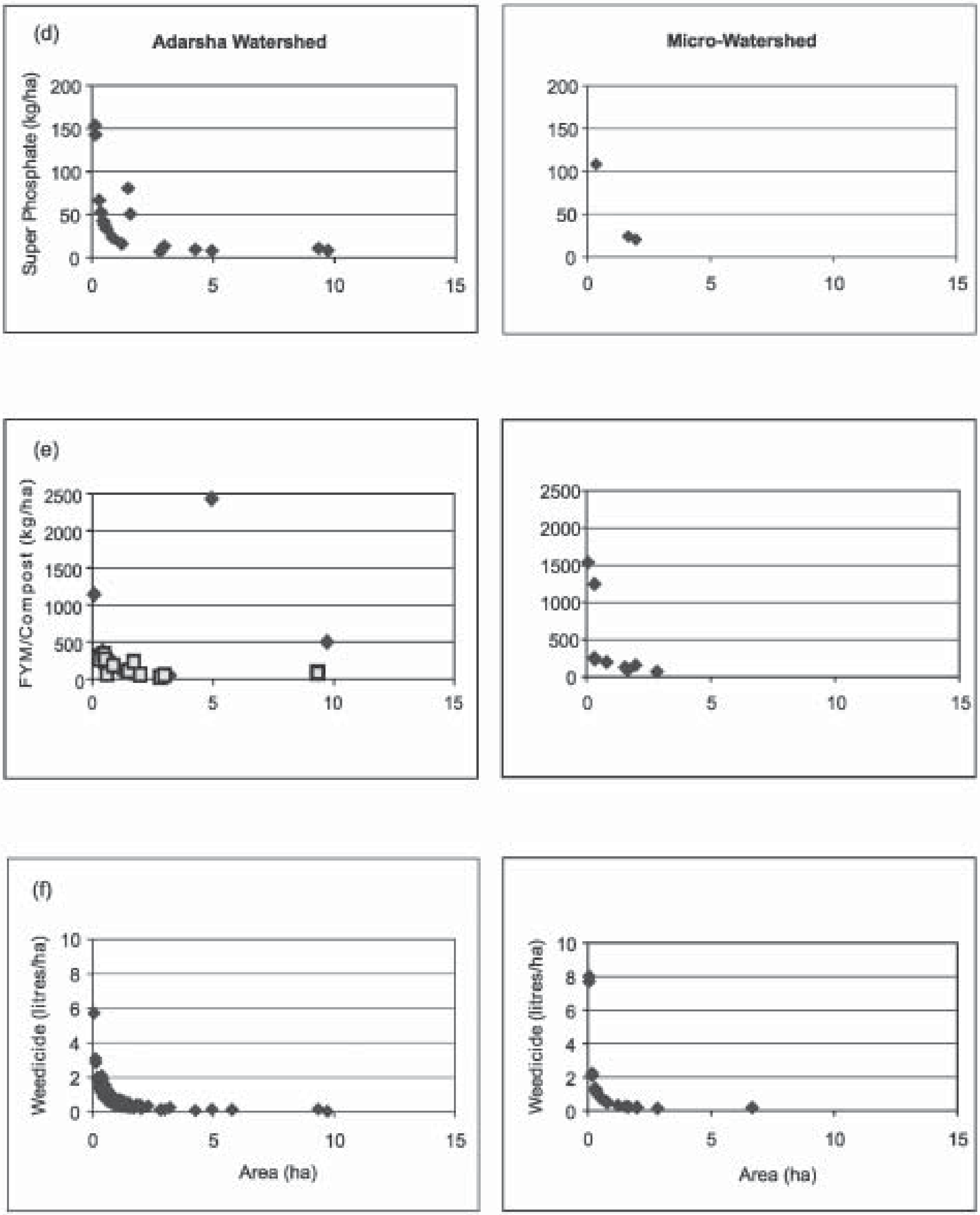
Backward castes possessed more number of bullocks, both local and improved breed, milch cows, young stock of cattle and buffaloes, goats, sheep, poultry and she buffaloes (Table 9). The possession of livestock by other castes is found to be very meager except for muslims who held more number of sheep at the time of survey.

Table 9. Number of livestock possessed by the families based on their caste.

Caste/ religion	Bullock's improved breed	Bullock's local	Milch cows cross-breed	Young stock cattle	Young stock buffalo	Goats	Sheep	Poultry	She buffalo
Unknown	0	2	0	0	0	1	0	0	0
Muslims	0	7	1	1	5	7	30	13	5
Other Castes	0	6	0	0	7	1	0	0	7
Backward Caste	6	30	4	5	8	24	15	19	12
Schedule Caste	0	6	1	1	3	8	0	3	3



(a)
Adarsha Watershed
DAP (kg/ ha)
Micro-Watershed
(b)
Urea (kg/ha)
(c)
Potash (kg/ha)
Area (ha)
Potash (Kg/ha)
Area (ha)


(d)
Adarsha Watershed
Micro-Watershed
Super Phosphate (kg/ha)
(e)
FYM/Compost (kg/ha)
(f)
Weedicide (litres/ha)
Area (ha)

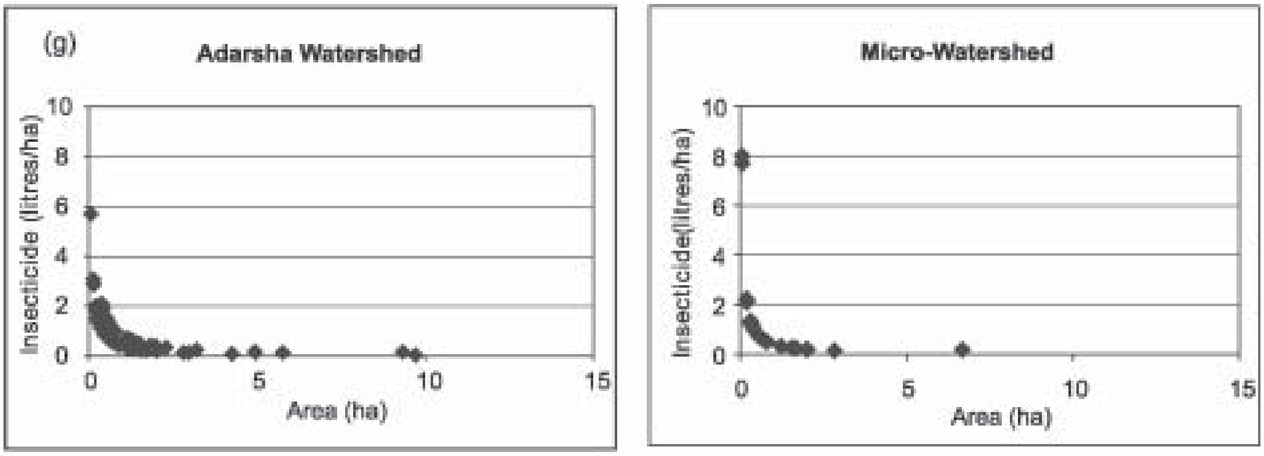


Figure 13. Inputs used (fertilizers both organic and inorganic, pesticides, weedicides) in Adarsha Watershed and in micro-watershed at Kothapally.

Reasons for inverse relationship – causative factors

Irrigation

The study indicated an inverse relationship between farm size and the proportion of total farm area under irrigation. The hypothesis is that this is an important technical factor for the inverse relationship between farm size and productivity. It is difficult to draw a direct relationship between proportion of irrigated area and productivity in Kothapally. The mean proportion of irrigated land per household did show a general decrease with increasing farm size. The mean proportion of small, medium and large farms being 0.84, 0.44 and 0.45. However, because the absolute numbers of farms provided with irrigation within the small and medium size groupings were small, this may be misleading. Despite these uncertainties, the relatively high availability of family labor per hectare on small farms might enable them to devote more labor to the creation and maintenance of irrigation facilities which, in turn, improves the quality of the soil. The availability of family labor on small farms was relatively high compared to the other farmers in Kothapally.

Labor

The availability of the labor was a major constraint for crop production in Adarsha Watershed, Kothapally. This was especially true during peak times such as sowing and harvesting, and if major labor shortages existed, then great losses in terms of productivity and profits occur. Every respondent who required additional labor outside the family stated that a labor shortage existed in Kothapally. However, this problem was more serious for larger landholders. Family size from small to large landholders remained fairly constant and so a relationship of decreasing labor availability per hectare with increasing land size was seen. The mean number of family labor per hectare in Kothapally for small, medium and large landholders was 8, 3 and 1, respectively. An instructive example was the case of chickpea crop where the farmers preferred to sell the crop at the green pod stage (one month before the harvest of the crop) itself, taking the advantage of the proximity to the city, where good market existed for green chickpea. People outside the village took the responsibility of harvesting the crop and helping the village farmers to overcome the labor problem.

Difference in land utilization between small and large landholders

Large farms underutilized the total land area that was at their disposal in comparison to small farms. This relative underutilization of land may have occurred because of either less irrigation availability or unwillingness to invest a high quantum of resources owing to the risk-aversion mentality. The data showed how irrigation and other inputs such as fertilizers, pesticide and FYM, decreased with increasing land size in Kothapally, with labor unavailability as one of the main constraints. These were the technical reasons for land underutilization by large landholders, but there were other more complex and subtle social reasons for why the land of the upper castes was underutilized.

Farmers belonging to upper castes often had a principal occupation other than agriculture, and large landholders sometimes held or purchased land for reasons other than its use as a productive resource. This case was highlighted in Kothapally within micro-watershed, with two large landowners both practising medicine in Hyderabad city. They do not live in Kothapally village and leased out their land to agricultural workers from another village. This may be an example of the fact that many large landowners held their land as a portfolio investment, and its possession may represent a hedge against inflation or a form of consumption as distinct from productive investment. This latter point might reflect the possession of land as a source of social prestige and the political influence this prestige confers.

The social dynamics within Kothapally clearly determined in some way the inverse relationship between land size and productivity. Ellis (1988) suggests that besides partial explanations such as prestige and landholding, the variations in productivity require overall economic explanations outside the technical condition of farm production. Ellis asserts that small farmers confront a low price, or in fact no cost, for labor combined with high prices for land and capital. These differences in relative factor prices results in (1) small farmers committing more labor to production than large farmers, (2) large farmers treating land as a relative abundant resource even in land scarce economy, (3) large farmers substituting machines for labor even in the capital-scarce labor abundant economy, and (4) larger farmers being overall less socially efficient agricultural producers than small farmers.

It seems that (1) and possibly (2) are economic reasons for small farmers having greater crop productivity than larger farmers in Kothapally. However, (3) and (4) are open to debate. Of the five large landholders surveyed in the Kothapally sample, one had recently purchased a tractor. Such machinery would undoubtedly make agricultural operations easier and more efficient. However, it is unknown how many agricultural laborers would lose employment opportunities because of this. Large landholders in Kothapally have emphasized the scarcity of labor. Perhaps the use of machine would make no impact upon an already labor scarce economy except on those large landholders.

Conclusion

In Kothapally village, more than half of the population belongs to backward communities and caste always played an important role at the education level. The village is characterized by constraints which include a low level of literacy as more than 80 percent of the children and adults have no education. Gender also played an important role for people to have some form of education. Like in the other rural parts of India, less than 10 percent of females go to school in Kothapally. The proportion of irrigated area (20%) is very less and most of the area is rainfed. Well-documented inverse relationship between land size and productivity is present in this village. The diversity in the cropping system during the rainy and postrainy season is a risk-aversion strategy being adopted by the farmers to face the vagaries of the monsoon, scarcity of labor and other contributing factors, which affect the yield of the crops. Most of the crops have low productivity (less than 1 t ha^{-1}). The above conditions provide an ideal setting to demonstrate that through optimum inputs and crop management practices these constraints could be solved.

References

Beteille A. 1974. Studies in Agrarian Social Structure. New Delhi, India: Oxford University Press.

Ellis F. 1988. Peasant Economics – Farm Households and Agrarian Development. Cambridge, UK: Cambridge University Press.

NCAER (National Council for Applied Economics and Research). 2001. South Indian Human Development Report. New Delhi, India: Oxford University Press.

Shiv Kumar AK. 1991. UNDP'S Human Development Index: A Computation for Indian States, Economic and Political Weekly, 22 October.

Lateri Watershed, Vidisha, Madhya Pradesh, India

PVS Rao, AB Pande, PK Joshi, SP Wani and P Pathak

Location

The Lateri watershed is located in the northwest corner of Vidisha district in Madhya Pradesh in central India (Figure 1). Madhya Pradesh is the largest state of the country and extends into three agro-ecological zones (7, 8 and 9) and the catchment area of the four major rivers, ie, Yamuna, Ganga, Narmada and Godavari. The state is divided into six physiographic regions. The district of Vidisha is located in the Vindhya Plateau Zone. The Lateri block is considered the most underdeveloped area within the district of Vidisha, with very limited irrigation and no major or medium-scale industry. The average rainfall is 1100 mm. The soils of the area are predominantly medium black and to some extent red soils. Agriculture is the main occupation in the black soil area, but employment is available only seasonally because of less crop intensity owing to less irrigation intensity. Twenty percent of the population from Lateri block migrates seasonally. The postrainy season *(rabi)* is the main cropping season when about 35,000 ha are sown while only about 10,000 ha is sown during the rainy season *(kharif)*. Double cropping is undertaken on only 3750 ha (Rangnekar 1999).

The Milli watershed in the Lateri block is spread over 10,000 ha, which is located in the core soybean production zone. It receives about 1100 mm rainfall, mainly during June to September. The landscape is extensively degraded because of sheet and gully erosion. A 100 ha sub-watershed is delineated for intensive soil loss and runoff monitoring on an operational-scale.

Methodology

Primary data was collected from 102 households of 7 villages and it was analyzed. The data was collected using an interview schedule (Appendix 2), which was filled by trained investigators through regional interviews. The schedule for data collection was prepared by the scientists of Socio-Economics and Policy Program, ICRISAT. The questionnaire followed is given in Appendix 2. The sample of the study is presented in the following sections.

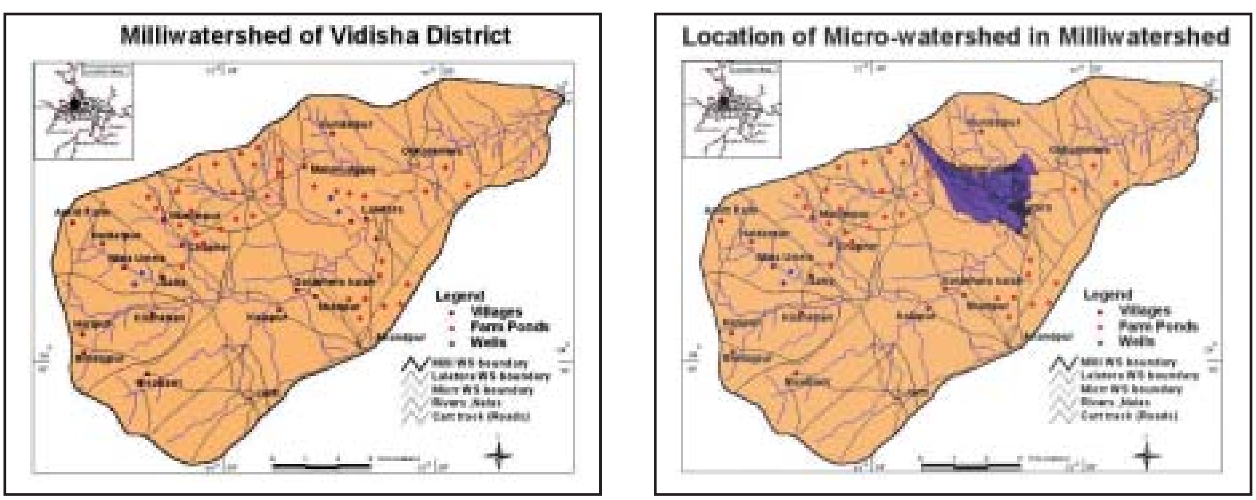


Figure 1. Milli Watershed and micro-watershed in the Milli watershed.

Farmer classification

Out of the total 102 households, 56 percent were small landholders (landholding less than 2.5 ha), 30 percent were medium landholders (landholding of 2.5 to 10 ha) and 15 percent were large landholders (10–30 ha). Out of the small, medium and large landholders, more than 40 percent from each group were holding lands in the bottom parts of the toposequence and the rest hold land in the middle and top parts of the toposequence (Table 1).

Table 1. Number of farmers in each toposequence.

Toposequence position	Small farmers (0–2.5 ha)	Medium farmers (>2.5–10 ha)	Large farmers (>10–30 ha)
Top	17 (30)*	7 (23)	2 (13)
Middle	14 (25)	10 (33)	3 (20)
Bottom	26 (46)	13 (43)	10 (67)
Total	57	30	15

* Values in parenthesis indicate percentages.

Education levels

About 60 percent of the small landholders were uneducated, only 24 percent attended primary school and 15 percent attended the secondary and high schools. Of the medium landholders, 53 percent were uneducated, only 30 percent had been to primary school and 16 percent to secondary and high schools. Of the large landholders, only 20 percent were not educated, 46 percent attended primary school and around 33 percent attended the secondary and high schools.

The data in Table 2 reviews a relationship between landholding size and level of education in this watershed. It can be stated that, with the increase in landholdings, the education levels improved in these villages. The average number of persons in the family with zero, pre-school, elementary, secondary school and college level of education in the watershed were 3.26, 1.92, 0.5, 0.23 and 0.15, respectively.

Livelihood source

Main source of the livelihoods in the watershed were from agriculture and related activities. Main source of the income for 93 percent of small, medium and large landholders was agriculture. Only 5 percent were agricultural laborers and 2 percent were in government services (Table 3).

The average size of the household was 9.37 persons out of which 5.25 are males and 4.12 were females. Out of 102 households, half of the households had a family size less than the average. About

Table 2. Education levels of small, medium and large landholders.

Education	Small Farmers	Medium Farmers	Large Farmers
Uneducated	34 (60)*	16 (53)	3 (20)
Primary School	14 (24)	9 (30)	7 (46)
Secondary School	6 (10)	3 (10)	3 (20)
High School	3 (5)	2 (6)	2 (13)

* Values in parenthesis indicate percentages.

Table 3. Main source of income (Total number of farmers in each category).

	Small farmer			Medium farmer			Large farmer		
Toposequence	a	b	c	a	b	c	a	b	c
Top	16	1	0	3	3	1	2	0	0
Middle	13	0	1	10	0	0	3	0	0
Bottom	25	1	0	13	0	0	10	0	0
Total	54	2	1	26	3	1	15	0	0

a =Agriculture; b = Agricultural laborer; c = Government service

10% of the households were just around the average, while the remaining 40% had family sizes more than the average. The average age of the household head was about 44 years. The family size of the landless laborers was much smaller at 5.5 persons per household. One hypothesis is that because the income and asset levels are lower, these households reduce the size of the family. The availability of labor was seasonal and a greater family size would require them to migrate. A recent study (Vadivelu et al. 2001) reveals that in most of the cases people with some landholdings enter into share cropping contracts and these people 'crowd-out' the landless share croppers from the share cropping market. It seems that small landholders have a better knowledge of agricultural operations and are in a better position to pay back loan borrowed from the landlord (through growing wheat than the landless share cropper from his own land).

Landholdings and land use

The surveyed households in this watershed primarily relied on agriculture for their livelihoods. Some 97% of the households ranked agriculture as their primary occupation. The majority of the farmers did not have any secondary source of income. Farmers' landholdings included wetlands (irrigated) and drylands (non-irrigated), distributed across different topographic locations in the watershed. The correct responses indicated that some 83% of the land was located in middle toposequence, while the remaining 17% was almost equally distributed along the bottom and top of a toposequence in the watershed. The results from 47% valid responses indicated that the soil depth ranged between 0.5 m to about 4 m on some lands. Few of the farms (about 11%) indicated soil depths less than 1 m of the valid response, 73% indicated an average soil depth on the farm ranging between 2 to 3 m.

The average total owned farm size (including cultivated, fallow and leased out and share cropped land) in the area was 5.04 ha, which amounted to 0.83 ha per capita. The average own cultivated land was about 4.794 ha, of which the average irrigated cultivated land was 0.855 ha (18%) and dryland was 3.938 ha (82%), indicating a per capita ownership of 0.14 ha and 0.64 ha, respectively.

The total land cultivated in *rabi* and *kharif* by the small, medium and large landholders is shown on a toposequence in Table 4. Of the total 84.5 ha land for smallholders, 23 ha were located at the top of the watershed, 20 ha in the middle and 42 ha in the bottom part. For the medium landholders, out of total 150 ha land, 3 ha were located at the top, 44 ha in the middle and 71 ha in the bottom part of the watershed. Among the large landholders, 26 ha were at the top, 41 ha in the middle and 186 ha at the bottom of the watershed (Table 4). For all the categories, cultivated land was more in the *rabi* season than in the *kharif* season.

Table 4. Total landholdings (ha) of small, medium and large landholders.

Toposequence	Small farmer			Medium farmer			Large farmer		
	Rabi	Kharif	Total	Rabi	Kharif	Total	Rabi	Kharif	Total
Top	4.25	4.25	23.00	32.75	4.25	35.25	20.00	6.00	26.00
Middle	21.13	2.75	19.88	44.00	6.75	44.25	41.25	2.75	41.25
Bottom	39.63	15.75	41.63	65.00	6.00	70.50	172.75	23.25	185.50
Total	65.01	22.75	84.51	141.75	17.00	150.00	252.00	32.00	252.75

Soils

The Lalatora watershed in particular was spread on the Deccan Trap basalt where the parent material is mainly alluvial. Majority of the land area consisted of black or black/alluvial type of soils for all the landholder categories (Table 5) with fine type of soil texture (Table 6). The physiography of the area was very gently sloping land where certain pockets towards the north of the area were highly gullied creating a certain amount of relief, which might create further problems of management. Totally, five soils series were identified. These were Vertisols characterized by grey, very deep, dark grayish brown to olive brown with a clayey surface horizon and calcareous B horizon. The predominant clay mineral was montmoillonite. These soils have greater micropore volume because of high amount of very fine clay present in the soil (NBSS&LUP 2000).

Rainfall

Table 7 reflects the variation in the amount of rainfall over an 8-year period (ranging from 803 mm to 1136 mm per year). The variation during the sowing period was also high (ranging from 276 mm to 630 mm). The major irrigation sources for all the category farmers were pond and river (Table 8).

Table 5. Soil type, total area in ha (No. of farmers in parentheses).

	Small farmer						Medium farmer						Large farmer					
Toposequence	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Top	22.5 (16)	0	0	0.5	0	0	35.25 (7)	0	0	0	0	0	0	0	0	26 (2)		0
Middle	10.37 (8)	7.5 (5)	2 (1)	0	0	0	41.25 (9)	0	3 (1)	0	0	0	0	0	0	11 (1)	17.5 (1)	12.75 (1)
Bottom	20.75 (13)	1.25 (2)	7 (4)	9.15 (5)	0	3.5 (2)	48.25 (8)	0	0	17.25 (4)	0	0	38 (3)	0	0	120 (6)	27.5 (1)	0

1. Black; 2. Red; 3. Alluvial; 4. Black/Alluvial; 5. N/A.

Table 6. Soil texture, total area in ha (No. of farmers in parentheses)

	Small farmer					Medium farmer					Large farmer				
Toposequence	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Top	15.5 (10)	0	0.5 (1)	0	7 (6)	18.75 (4)	0	5 (1)	0	11.5 (2)	15 (1)	0	0	11 (1)	0
Middle	8 (6)	0	4.5 (3)	0	7.37 (5)	29.25 (7)	0	6 (2)	0	9 (1)	30.25 (2)	0	11 (1)	0	0
Bottom	32.12 (19)	0.5 (1)	0.25 (1)	2 (1)	6.25 (4)	53.25 (9)	0	3.75 (1)	6.75 (2)	6.75 (1)	155.5 (8)	0	17.5 (1)	12.5 (1)	0

Table 7. Rainfall in Lalatora watershed (mm).

Month	1989	1990	1991	1992	1993	1994	1995	1996
January	28	264	71	8	94	244	26	478
June	276	333	346	281	278	444	238	630
April	407	377	388	650	288	333	280	28
September	92	339	19	133	564	166	128	60
October	-	33	-	-	-	-	-	-
Total	803	1346	824	1072	1224	1187	672	1196

Collected from IMD rainguage at block level.

Table 8. Irrigation source (No. of farmers)

	Small farmer						Medium farmer						Large farmer					
Toposequence	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Top	8	0	0	0	0	9	1	0	0	0	1	5	1	0	0	1	0	0
Middle	3	0	1	1	0	6	1	0	0	2	0	4	2	0	0	0	0	1
Bottom	2	11	1	0	0	8	2	8	0	0	0	3	0	3	2	0	0	3
Total	13	11	2	1	0	23	4	8	0	2	1	12	3	3	2	1	0	4

1. Pond; 2. River; 3. Causeway; 4. Borewell; 5. Tap; 6. None.

Crop production and cropping pattern

In this area, crops grown as intercrops on the same field include wheat and chickpea during *rabi,* and soybean and maize during the rainy season. Wheat and chickpea were also sown as sole crops. Other crops like paddy and lentils were grown as sole crops to a small extent. In *kharif* season, farmers grew soybean (43% of respondents) while very few farmers grew maize and sorghum (less than 2% of respondents). In the *rabi* season, wheat was the most frequently occurring crop in the area, followed by chickpea. About 89% and 86% of the sample farmers reported growing wheat and chickpea, mainly as sole crops in the *rabi* season. The other relatively less important crops were paddy grown by about 10%, and lentil grown by about 7% of the farmers. All the postrainy season crops seemed to get some supplementary irrigation, while fertilizer was used on wheat, chickpea and lentils.

The major crop grown in rainy season was soybean over different parts of the toposequence (Table 9). Sorghum in about 2 ha was grown in the bottom part of the toposequence by the large landholders.

In the postrainy season, wheat and chickpea were the major crops grown by small, medium and large landholders (Table 10). Wheat was grown in about 38 ha in the top, in 77.5 ha in the middle

Table 9. Crops grown (ha) in ***Kharif*** season.

Toposequence	Crop	Small farmers	Medium farmers	Large farmers
Top	Soybean	7.25	4.25	7
	Sorghum	0.5	-	-
	Maize	-	1	-
Middle	Soybean	2.5	6.75	2.75
Bottom	Soybean	20.75	13	24
	Sorghum	-	0.50	0.75

- Not cropped

Table 10. Cropping for Rabi season in ha.				
Toposequence	Crop	Small farmers	Medium farmers	Large farmers
Top	Wheat	14	15.3	9
	Chickpea	9.75	11.85	12.75
	Paddy	1	8.85	1.75
	Lentil	-	-	0.75
Middle	Wheat	39.5	20.5	17.5
	Chickpea	9.75	14.75	15
	Paddy	0.75	1.75	2.5
	Lentil	-	0.5	-
	Coriander	-	-	3.5
Bottom	Wheat	23.12	44.5	60
	Chickpea	18.12	1	63.75
	Paddy	0.5	0.5	25.25
	Oilseed	-	0.5	-

- Not cropped.

and 127.6 ha in the bottom parts of the toposequence. Chickpea was grown in about 34 ha in the top, 40 ha in the middle and 113 ha in the bottom parts of the toposequence. Paddy was also grown at the top and middle parts of the toposequence in about 12 ha and 5 ha of land, respectively, whereas in the bottom part of the toposequence, large landholders used about 25 ha for paddy cultivation (Table 10).

The other major rainy season crops were sorghum and maize. Vegetables and spices such as coriander and ginger were grown by progressive farmers with good resources.

Fertilizer input

Use of inorganic fertilizers in this area was only 75%. Adoption of fertilizers seemed to be spread over a long time. Few farmers started using it in the eighties and many more adopted it in the nineties. Few farmers also indicated first use around the time of the survey (1999). Those who chose to use fertilizers seemed to have continued the use. More work needs to be done to investigate the major constraints that prohibit a quarter of farmers in the area from using fertilizers. Despite the limited use of inorganic fertilizers, only 60% of the sample farmers indicated using FYM. None, however, indicated using other sources such as green manures and crop residues to replenish soil nutrients. This perhaps indicates a high level of soil nutrient depletion in this watershed, as the addition of external inputs to restore soil fertility and nutrients removed with the harvest and soil erosion seems to be limited.

The fertilizer usage was more by the small landholders followed by medium landholders and large landholders. Small farmers with the fields at the bottom of a toposequence use about 318 kg DAP ha^{-1}, 300 kg urea ha^{-1}, 198 kg FYM ha^{-1} and 75 kg Growmore fertilizer ha^{-1}. Medium farmers use about 432 kg DAP ha^{-1}, 435 kg Urea ha^{-1}, 197 kg FYM ha^{-1}, 26 kg Growmore fertilizer ha^{-1}, and 23 kg super phosphate ha^{-1} (Table 11). Large farmers having fields at the bottom of a toposequence used more quantity of fertilizers than that of those having fields at the middle and top of a toposequence.

Livestock ownership

The major types of livestock in the areas included cattle, buffaloes, goats, sheep and poultry. About 86% of the respondents owned some livestock in addition to crop production activities. The average ownership of different types of animals per household were bullocks – 2, milking cows – 1.5, young

Table 11. Average Fertilizer Input (Total kg ha^{-1}).

	Small farmer					Medium farmer					Large farmer				
Toposequence	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Top	171	176	161	0	33	100	102	32	0	23	30	30	4	0	25
Middle	169	156	124	40	0	147	141	108	9	0	45	45	1	9	0
Bottom	318	300	198	75	0	185	192	57	17	0	151	140	6	19	0
Total	658	632	483	115	33	432	435	197	26	23	226	215	11	28	25

1. DAP; 2. Urea; 3. FYM; 4. Growmore; 5. Super phosphate.

cattles – 2.5, he buffaloes – 1.5, she buffaloes – 3, young buffaloes – 2, goats – 5 and poultry – 3. In Lalatora, cows were the most popular stock in about 60% of the households, followed by bullocks (55%) and she buffaloes (43%). Only about 5% of the households maintained goats while none raised any sheep. The average value of livestock wealth was Rs. 22,000 per household.

The livestock (bullocks, cows, calves, buffaloes, goats, hen) ownership details are given in Table 12. The large landholders owned most of the livestock (bullocks, calves and hen) in the village. Out of the three zones in the toposequence, the large landholders of the bottom zone had most livestock compared to the medium and top parts of the toposequence (Table 12).

Farm implements ownership

Farmers in the watershed possessed other assets and implements (such as tractors, bicycles, plows, seed drills and bullock carts) which were mainly used in the process of crop and livestock production (Table 13). The average farm equipment and related wealth for sample households was Rs 49,873. Of this, some 50% of the households possessed assets worth less than Rs 10,000. About 30% owned assets worth between Rs 10,000 and 30,000. The holding structure of important assets showed that 16% of the households owned a tractor and about 6% owned a thresher. More than 58% of the households owned a seed drill, but only less than 1% owned sprayers. A large number of farmers owned wooden plows and bullock carts.

In this village, the small landholders followed by medium and large landholders owned most of the farm implements. Out of the small landholders, the landholders of the bottom zone owned more farm implements than that of the farmers of top and medium zones. The same trend was observed for medium and large landholders across the toposequence.

Crop Productivities

Crop productivity within zones and land sizes

The productivity for each crop within top, medium and bottom zones of the toposequence and small, medium and large landholders during *kharif* and *rabi* seasons has been tabulated in Tables 14 and 15, respectively.

Kharif season

Top zone

Small farmers: The productivity of soybean (0.54 t ha^{-1} of grain and 0.57 t ha^{-1} of fodder) was higher than that of sorghum (0.16 t ha^{-1} of grain and 0.16 t ha^{-1} of fodder).

Table 12. Livestock (total number of livestock in each category).

		Small farmers				Medium farmers				Large farmers			
Topo-sequence	Livestock	No of farmers	No of live-stock	Total value	Average value/ household	No of farmers	No of Live-stock	Total value	Average value/ household	No of farmers	No of Live-stock	Total value	Average value/ household
Top zone	Bullock	7	13	50000	7142	4	8	22600	5650	*	*	*	*
	Cow	6	7	8500	1214	6	7	11750	1958	2	3	9650	4825
	Calf	6	7	2800	400	6	9	3600	600	2	3	1200	600
	She buffalo	4	4	26000	6500	3	5	30000	10000	2	3	13000	6500
	He buffalo	1	1	2000	2000	3	3	4000	1333	1	1	500	500
	Young buffalo	3	3	6300	2100	2	2	4000	2000	2	5	8000	4000
	Hen	1	5	1000	1000	*	*	*	*	*	*	*	*
	None	5	0	0	0	*	*	*	*	*	*	*	*
Middle zone	Bullock	8	16	96000	12000	6	12	119000	19833	2	3	9500	4750
	Cow	7	9	24700	3528	5	6	9900	1980	1	1	1500	1500
	Calf	8	13	22925	2865	7	15	38000	5428	3	6	3800	1266
	She buffalo	3	3	13000	4333	4	4	23000	5750	3	6	36000	12000
	He buffalo	*	*	*	*	*	*	*	*	*	*	*	*
	Young buffalo	1	1	400	400	3	4	6200	2066	3	5	3300	1100
	Goat	2	20	9000	45000	1	7	29400	29400	*	*	*	*
	Hen	2	16	15600	7800	1	2	600	600	*	*	*	*
	None	3	0	0	0	1	0	0	0	*	*	*	*
Bottom zone	Bullock	11	22	134000	12181	14	28	236200	1671	6	13	73000	12166
	Cow	15	22	70500	4700	13	20	62100	4776	10	20	106600	10660
	Calf	12	22	25150	2095	15	32	49900	3326	10	27	43000	4300
	She buffalo	5	7	56000	11200	12	18	161200	13433	10	25	253000	25300
	He buffalo	*	*	*	*	3	3	7000	2333	1	2	4000	4000
	Young buffalo	4	6	18500	4625	8	13	19000	2375	9	19	29700	3300
	Goat	2	6	13700	6850	*	*	*	*	*	*	*	*
	Hen	5	28	42700	8540	*	*	*	*	*	*	*	*
	None	*	*	*	*	1	0	0	0	*	*	*	*

* Nil

Table 13. Farm implements (total number of farm implements in each category of the toposequence).

Toposequence	Farm implement	Small farmer	Total value in Rs.	Medium farmer	Total Value in Rs.	Large farmers	Total value in Rs.
Top zone	Axe	17	1015	13	525	5	150
	Blade harrow	4	2000	4	2000	0	0
	Bullock cart	1	2500	3	24500	0	0
	Crowbar	2	250	3	170	1	100
	Cultivator	0	0	1	7000	2	14000
	Cycle	3	4000	1	1500	1	1500
	Electric motor	6	54700	2	7000	1	5000
	Grain storage	0	0	0	0	5	2000
	Khurpi	27	265	19	145	4	45
	Oil Engine	2	29000	0	0	1	17500
	Sickle	32	680	20	355	6	85
	Soil Container	10	480	7	400	4	300
	Spade	8	470	5	250	3	110
	Seed drill	8	4800	4	2600	0	0
	Thrasher	1	25000	0	0	1	18000
	Tractor	0	0	1	238000	2	506500
	Trolley	0	0	1	32000	2	71000
	Wooden plough	6	7500	4	2000	0	0
Total		127	132660	88	318445	38	636290
Middle zone	Axe	27	1710	23	1185	0	560
	Blade harrow	6	2400	6	2400	4	1800
	Bullock cart	6	46000	4	4100	1	10000
	Crowbar	3	280	5	260	4	500
	Cultivator	0	0	2	9000	2	12000
	Cycle	3	4200	4	5500	2	3000
	Electric motor	3	38000	2	40000	1	6000
	Grain storage	13	6900	15	8500	22	3575
	Khurpi	25	314	22	323	12	169
	Seed drill	8	3050	10	7500	3	500
	Sickle	35	1050	34	870	20	555
	Soil Container	12	930	11	1270	12	4100
	Spade	11	575	9	470	7	320
	Sprayer	0	0	1	900	0	0
	Thrasher	2	40000	1	10000	0	0
	Tractor	3	280000	2	300000	2	482000
	Trolley	0	0	0	0	2	61000
	Wooden plough	10	2200	4	1300	5	950
	Oil engine	0	0	0	0	2	950
Total		167	427609	155	393578	101	587979
Bottom zone	Axe	40	1975	30	1550	33	1025
	Blade harrow	8	3700	7	2400	3	3000
	Bullock cart	12	85000	12	70100	5	3000
	Crowbar	14	840	10	730	12	950
	Cultivator	0	0	0	0	6	45000
	Cycle	9	12400	7	9200	4	5700

... Continued

Table 13. ***Continued...***

Toposequence	Farm implement	Small farmer	Total value in Rs.	Medium farmer	Total Value in Rs.	Large farmers	Total value in Rs.
	Electric motor	4	61000	2	27000	6	87000
	Grain storage	5	4500	5	12000	7	31150
	Khurpi	40	933	32	695	28	415
	Seed drill	14	6600	14	6350	4	900
	Sickle	79	1540	50	1355	44	715
	Soil Container	32	1460	19	985	30	1295
	Spade	21	1130	18	1090	18	1035
	Thrasher	0	0	0	0	1	50000
	Tractor	0	0	0	0	6	1605000
	Trolley	0	0	0	0	6	218000
	Wooden plough	16	5750	13	3750	7	2100
	Oil engine	1	15000	1	10000	3	45000
	Duster	1	300	0	0	0	0
	Iron Plough	0	0	1	500	1	500
Total		296	202128	221	147705	224	2101785
Grand total		590	762397	464	859728	363	3326054

Table 14. Average Crop yields (t ha^{-1}) during ***kharif*** season 1999.

Toposequence		Small farmers		Medium farmers		Large farmers	
	Crop name	Grain	Fodder	Grain	Fodder	Grain	Fodder
Top zone	Soybean	0.54	0.57	0.16	0.12	0.89	0.89
	Sorghum	0.16	0.16	-	-	-	-
	Maize	-	-	0.10	0.02	-	-
Middle zone	Soybean	1.20	1.04	0.65	0.56	0.91	0.80
Bottom zone	Soybean	0.38	0.37	0.40	0.30	0.90	0.72
	Sorghum	-	-	1.00	0.40	1.33	0.67

- Not cropped

Medium farmers: Soybean productivity of the medium farmers (0.16 t ha^{-1} of grain and 0.12 t ha^{-1} of fodder) was nearly one-fourth of the productivity of small farmers.

Large farmers: Large farmers achieved the highest yield of soybean (grain 0.89 t ha^{-1} and fodder 0.89 t ha^{-1}) followed by small and medium farmers.

Middle zone

Among the farmers' groups in this zone, the productivity of the small farmers (grain 1.2 t ha^{-1} and fodder 1.04 t ha^{-1}) was higher than that of the medium and small farmers.

Bottom zone

In this zone of the toposequence, large farmers obtained highest yield for soybean crop (0.9 t ha^{-1} of grain and 0.72 t ha^{-1} of fodder) when compared to medium and small farmers. Similarly, in the case of sorghum crop, the productivity of large farmers was greater than that of the medium farmers.

Table 15. Average Crop yields (t ha^{-1}) during ***rabi*** season 1999-2000.

Toposequence	Crop name	Small farmers Grain	Small farmers Fodder	Medium farmers Grain	Medium farmers Fodder	Large farmers Grain	Large farmers Fodder
Top zone	Wheat	0.85	0.76	0.54	0.37	1.02	1.02
	Chickpea	0.63	0.55	0.53	0.40	0.82	0.82
	Paddy	1.70	0.02	0.25	0.11	0.63	0.63
	Lentil	-	-	-	-	0.40	0.40
Middle zone	Wheat	1.36	0.27	1.08	0.71	1.04	0.60
	Chickpea	0.66	0.48	0.95	0.49	0.87	0.70
	Paddy	0.27	0	0.80	-	0.64	0
	Lentil	-	-	0.10	0.40	-	-
	Coriander	-	-	-	-	0.77	0
Bottom zone	Wheat	0.91	0.80	0.85	0.66	1.53	1.18
	Chickpea	0.84	0.61	0.69	0.46	0.80	0.64
	Paddy	0.40	0.40	-	-	0.02	0
	Oilseed	-	-	0.40	0.30	-	-

- Not cropped

Rabi season

Top zone

In this zone of the toposequence, during *rabi* season, grain and fodder yields of wheat and chickpea crops were more for large farmers followed by small and medium farmers. The yields of large farmers were two-fold higher than that of medium farmers. In the case of rice crop, more grain yield (1.7 t ha^{-1}) was observed for small farmers followed by large farmers (0.63 t ha^{-1}) and medium farmers (0.25 t ha^{-1}). Lentil crop was grown by the large farmers only. Yields were 0.4 t ha^{-1} of grain 0.4 t ha^{-1} of fodder.

Bottom zone

In this zone, the highest grain (1.53 t ha^{-1}) and fodder (1.18 t ha^{-1}) yields of wheat crop were observed for large farmers followed by small and medium farmers. In the case of chickpea, more grain yield (0.84 t ha^{-1}) was observed for small farmers when compared with large and medium landholders. Similarly, rice productivity of the small landholders was 20 folds more compared to large farmers. In this zone, oilseed was grown by medium farmers only.

Crop productivity in Lateri watershed

In the *kharif* season, in all toposequences and land sizes, the highest (8 folds) yields (grain and fodder) of the soybean crop was observed for small farmers in the middle zone and the lowest of the soybean was recorded for medium farmers in the top zone of the toposequence.

In the *rabi* season, in the case of wheat, the highest (4 folds) yields of grain and fodder were observed for large farmers in the bottom zone whereas the lowest yields were recorded in the middle zone for small landholders. In the case of chickpea, during *rabi* season, the highest grain yield (0.95 t ha^{-1}) was recorded for medium farmers in the top zone. In the case of paddy crop, during *rabi* season, in the middle zone of the toposequence, medium farmers recorded the highest (40 folds) grain yields and the lowest grain yield was noted among large landholders in the bottom zone.

When we look at the average yields, wheat and chickpea grown as sole crops had higher yields than the intercrops. As sole stands, *rabi* season wheat yields were about 1.2 t ha^{-1}, while chickpea yields were about 0.93 t ha^{-1}. In the rainy season, the average soybean yield from farmers' fields was about 758 kg ha^{-1}, whereas paddy provided about 600 kg ha^{-1}.

Cost of cultivation of soybean

- Land preparation cost – The cost of hiring a tractor is Rs 200 h^{-1}.
- Seed cost – Rs 12 kg^{-1}.
- Diammonium phosphate (DAP) – Rs 10 kg^{-1}.
- Single superphosphate – Rs 2.70 kg^{-1}.
- Average wage rates (per day) prevalent in the village:
  - Sowing – Rs 40.
  - Weeding – Rs 40 to Rs 50.
  - Harvesting – Rs 50 (up to Rs. 75 in peak demand)
- The imputed labor costs of the landlord (share cropper is not computed in calculating the costs).
- The cost of threshing is Rs 3 to 5 for 100 kg of threshed soybean.

ICRISAT provided technical support through the NGO during the first year and recommended best bet option treatment to trial farmers. The best bet option for soybean includes;

Thiram:bavistin – 1:2 ratio. Thiram and bavistin seed treatment (at 3 g kg^{-1} seed) helps in healthy crop stand.

- *Rhizobium* – 1.25 kg ha^{-1}.
- Phosphate solubilizing bacteria – 1.25 kg ha^{-1}.
- Murriate of potash – 50 kg ha^{-1}.
- Urea – 50 kg ha^{-1}.
- DAP – 125 kg ha^{-1}.

Relationship between soil, rainfall and cropping pattern

The soils had higher clay content characterized by greater water holding capacity and there was poor drainage with high probability of waterlogging and with an average rainfall of 970 mm. Higher rainfall intensity caused greater runoff which caused soil erosion. The problem therefore in the rainy season was poor drainage and waterlogging/runoff which lead to loss of fertile top soil.

Farmers preferred to grow the rainy season crop soybean in irrigable land as they could not take care of any risks of variation in rainfall during the crop cycle, and also the delayed harvest of soybean does not affect the growth of the postrainy season crop, chickpea/wheat. In the case of dryland plots, farmers preferred to leave land fallow. Farmers realized that sequential cropping was risky and indeed a study by Pandey (1986) found that in only about 9 out of 29 years, the residual moisture was sufficient for sequential cropping. The studies of Rosenweig and Binswanger (1993) in villages over 10 year period found that the risk-coping mechanisms (post-ante consumption smoothing mechanism are stronger) in wealthier families are better and they generally tend to take higher risk. Therefore one hypotheses that farmers with larger irrigable land are better-off farmers who can take the risks.

The average yield of all the crops except soybean was less in Lateri block than in Madhya Pradesh. The most important constraint of waterlogging in the rainy season required adequate drainage systems, 81.24% of the respondents categorized the adoption as 'partial', which, however, is hypothesized to be an over-estimation of the treatment undertaken. A recent study has found that the problem is a strong constraint and the drainage is unsatisfactory to tackle the enormous nature of the problem (Vadivelu et al. 2001) for estimates on the co-variation in output across farms and the losses suffered because of waterlogging during the 1999 rainy season. Most of the constraints listed for non-adoption were because of the lack of technical knowledge or the expensive nature of the perceived higher cost, which the farmer was not willing to invest. This calls for a properly designed treatment program with a reasonable contribution from the farmers to tackle the problem. Collective action to tackle the waterlogging problem demands cooperation (human and financial).

Summary and Conclusion

The major constraint in the watershed area is in terms of low cropping intensity as the majority of the land is left fallow during the rainy season. Waterlogging and soil erosion (top and middle zone) are the major constraints faced. The lack of initiative by the farmers is because of their perceived higher cost in undertaking these investments and they expect the government to take a lead role. The yields except for soybean in general are less than 1 t ha^{-1}. However, there is huge variation in the yields over years. The education level is poor and the women worse off as a Hindu version of the 'purdah' system is followed. The infrastructural facilities in terms of electricity, roads and telecommunications are in a poor condition.

References

NBSS&LUP (National Bureau of Soil Survey and Land Use Planning). 1999. Detailed soil survey of a part of Lalatora watershed. Nagpur 440 010, Maharashtra, India: NBSS&LUP.

Pandey S. 1986. Economics of water harvesting and supplementary irrigation in the semi-arid tropical region in India: a systems approach. Armidale, Australia: University of New England. 312 pp.

Rangnekar DV. 1999. Lateri – Another challenge for BAIF sustainable, integrated rural development in improving management of natural resources for sustainable rainfed agriculture. Proceedings of the pre-launch workshop, 16–18 December 1998. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Rosenweig and Binswanger. 1993. Wealth, weather risk and the composition and profitability of agricultural investments. Economic Journal, 103:56–78.

Vadivelu GA, Wani SP, Bhole LM and Pathak P. 2001. An empirical analysis of the relationship between size, ownership and productivity – New evidence from the semi-arid tropical region in Madhya Pradesh, India. Working paper series No. 4. Natural Resource Management Program, ICRISAT. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 50 pp.

Ringnodia Watershed, Indore, Madhya Pradesh, India

GP Saraf, RA Sharma, OP Verma and YS Chauhan

Location

The village Ringnodia is situated 22 km to the north of Indore city in Madhya Pradesh (22°43' N and 73° 54' E) on the Indore-Ujjain State Highway No. 27 at an altitude of about 600 m from the mean sea level and comes under Sanwer *Tehsil* in Indore district.

Methodology

The survey was undertaken in the treated area. Of the total 69 farm households, 64 were considered for the study. Only households with land were included in the survey. Data were collected using an interview schedule (Appendix 2) and the data pertains to the crop information for the period May 1999 to April 2000.

Table 1 provides information on landholdings and cropping intensity. Majority of the small and medium landholders had land as shared in whereas most of the large landholders either had land as leased out or shared out. Details of croping systems in the farmers' fields during 1999–2000 are depicted in Figure 1.

Table 1. Landholding information and cropping intensity.

Sl.No	Size group	Leased-in land (% of land holding)	Leased out land (% of land holding)	Share cropped in land (% of land holding)	Share cropped out land (% of land holding)	Current fallow (% of land holding)	Permanent fallow (% of land holding)	Cropping intensity
1	Small (0.1 to 2.0 ha)	Nil	Nil	6	Nil	10	Nil	104
2	Medium (2.1 to 4.0)	8	5	16	8	16	Nil	114
3	Large (above 4.1 ha)	Nil	25	Nil	25	25	Nil	122

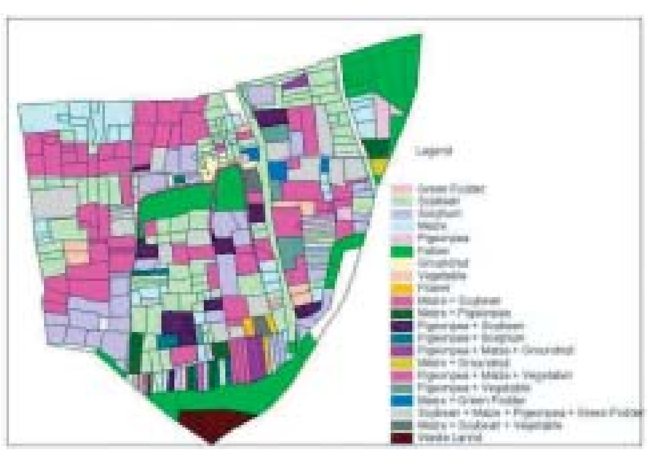


Figure 1. Cropping systems at Ringnodia watershed.

In the treated area, the small and marginal size farms had 41% sandy soil, 21% loamy soil and 38% clayey soil texture. The large farmers had the maximum, 60% of clayey soil in their possession with 31% loamy soil and only 9% of the land was of sandy texture in nature. The small and marginal farmers have the larger percentage of Alluvial soil (21%), followed by medium farmers (18%) and large farmers (17%) (Table 2).

Table 2. Soil characteristics of the farm holdings of treated farms in Ringnodia micro-watershed.

		Soil texture(%)			Soil type (%)			Topography (%)		
Sl.No	Size group	Sand	Loam	Clay	Alluvial	Red	Black	Up land	Mid land	Low land
1	Small and marginal (0.1 to 2.0 ha) farms	41	21	38	21	30	49	32	40	28
2	Medium (2.1 to 4.0 ha) farms	22	21	57	18	19	63	21	25	54
3	Large (above 4.1 ha) farms	9	31	60	17	18	65	15	34	51

The small and marginal farmers had most of their land in the midland area (40%) and upland (32%) with only 28% of the land in relatively more fertile low land area. In contrast, the medium (54%) and large farmers (51%) had most of the landholding in the low lying areas (Table 2).

The small and marginal farmers had only 19% of their land irrigated compared to 25% among medium landholders and 50% among large farmers. The major source of irrigation was through tubewells. While none of the small and marginal farmers had more than one tubewell, 8% of the medium and 25% of the large farmers possessed more than one tubewell (Table 3).

Crop Disposition

Small and marginal farmers

About 73% of the soybean crop was sold with 14% kept as seeds for future sowing, and about 12% was used as repayment in kind for the loans. The wheat crop was largely used for self consumption (52%), 20% of the produce was stored and 4% was used for loan repayment in kind, 3% was used as wage payment for the harvesting and threshing operations. The gram crop was sold to the extent of 60% and 18% was held for storage and only 8% was consumed. Potato crop 92% was marketed with only 8% being used for self-consumption (Table 4).

Medium farmers

Eighty percent of the soybean crop was sold to local middlemen. In harvesting and threshing operations, 3% of the total production was paid as wages in kind and 14% was stored. 53% of the wheat was sold, 15% of it was stored and the rest used for family consumption. In the case of chickpea, 35% of the crop was sold, 20% was stored and 43% was consumed by the family. In the case of potato, 97% of the crop was sold and the rest was used for self-consumption.

Table 3. Irrigation status (% of cultivated land) of treated farmers of Ringnodia micro-watershed.

Sl. No.	Size Group	Irrigated area %	Un-irrigated area %	Tube wells	Open wells with electric pump	Tank, farm ponds river	Water supply sufficient	Water supply in sufficient	No of tube wells more than 1
1	Small-marginal (0.1 to 2.0 ha)	19	81	94	12	nil	87	14	Nil
2	Medium (2.1 to 4.0 ha)	25	75	92	8	nil	83	17	8
3	Large (above 4.1 ha)	50	50	75	25	nil	75	25	25

Table 4. Crop disposition in 1999–2000, average production (kg ha^{-1}) in the proposed treatment area of Ringnodia micro-watershed.

Production and market price	Small and marginal farmers crop				Medium farmers crop				Large farmers crop			
	Soybean	Wheat	Chickpea	Potato	Soybean	Wheat	Chickpea	Potato	Soybean	Wheat	Chickpea	Potato
Main product (kg ha^{-1})	850	1680	710	18900	920	2510	790	19800	956	2470	800	21400
By product (kg ha^{-1})	1500	1800	750	Nil	1700	2700	840	Nil	1790	2300	850	Nil
Disposition marketed %	73	11	8	92	80	53	35	97	80	70	75	97
In kind payment	7	3	-	3	3	2	2	1	3	1	2	1.2
Loan repayment (%)	5	4	-	-	2	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Still held in storage (%)	14	20	18	Nil	14	15	20	Nil	16	26	21.5	Nil
Consumed (%)	Nil	52	60	8	Nil	30	43	2	Nil	0.5	0.5	0.5
Other (feed, damaged, gifted)(%)	1	Nil	nil	nil	1	-	-	1	1	1	1	1

Large farmers

Eighty percent of the soybean crop was sold with 16% stored as seeds and the rest was used as kind payment for wages to labor engaged for threshing. In this group, a large proportion, 70% of the wheat was sold and about 26% was stored and only 0.5% was consumed by the family and about 1% was either fed to milch animals or eaten away by rats. In the case of potato, 97% of the crop was sold, 15% of it was used as wage payment in kind and only 0.5% was used for self-consumption.

The major cause of the low yield was due to the adverse weather conditions and low rainfall. The poor resource base was also an important contributing factor (Table 5). Hence, the cropping intensity was low and most of the agricultural laborers were unable to get year-round employment.

Table 5. Yield and market price for the major crops during 1999-2000.

Sl. No.	Crop	Market rate (Rs. per quintal)	Yield kg ha^{-1}
1	Soybean	950-1050	900
2	Wheat	600-950	2200
3	Chickpea	950-1200	750
4	Potato	200-275	20000

Technology Adoption

Fertilizer and pesticide adoption

The application of farmyard manure (FYM) and the use of pesticides were low in all groups (Table 6a).

Table 6a. Fertilizer and pesticide usage by different groups of farmer.

		Landholding		
Sl. No.	Particulars	Small & marginal	Medium	Large
1	Using inorganic fertilizers	31	42	100
2	Started using fertilizer			
	Since last 5 years	79	83	50
	Since last 10 years	19	16	25
	Since last 15 years	2	8	25
3	Use of fertilizer every year	62	75	100
4	Application of FYM every year	6	8	25
	Every 2 years	8	16	25
	Every 3 years	12	16	50
	Every 5 years	46	67	Nil
	Never used in desired doses	31	8	50
5	Use of Pesticides			
	Started using pesticides	25	25	50
	Since last 5 years	25	25	50
	Since last 10 years	10	16	25
	Since last 15 years	nil	8	25
6	Ownership of fertilizer throughout	10	16	75
7	Availability of sprayer	19	25	100
8	Availability of fertilizer throughout year	46	50	50
9	Availability of pesticides throughout the year	62	75	75

Soil & Water conservation practices

Small farmers

Keyline cultivation was not implemented/adopted by any of the farmers, because of the lack of knowledge about the practice. Leveling and smoothing was practised in at least one field by 79 small farmers, 12% reported that it was not technically suitable in their location, 8% reported that it was costly. Dug out ponds were not in use, with 19% reporting lack of knowledge and 92% reported that it was not technically suitable. The construction of ponds was expressed as a costly option by 92% of the respondents, 87% of them said that there would not be any cooperation among the farmers for such a venture. Sixty-two percent of the respondents reported lack of knowledge on the construction of waste weirs, 42% considered it to be not technically suitable, 62% reported that it was a costly option. Deep ploughing was considered as unsuitable for their locations by 42% of the respondents and 92% of them considered it costly.

Medium farmers

Keyline cultivation was not known and considered inconvenient by 92% of the respondents; 16% found it technically not suitable to their specific locations; 25% reported that it was a costly option. Leveling and smoothing was considered inconvenient by 50% of the respondents, while 25% of them considered it too costly. Dug out farm ponds were considered technically suitable by 92% of the respondents and all of them considered it to be costly. There was no knowledge on waste water weirs by 42% of the respondents, 25% reported that it was not technically feasible and 75% of them considered it costly and 92% of them said that the neighboring farmers would not agree to it.

Large farmers

There was no knowledge of keyline cultivation by 75% of the farmers and 25% were of the view that it was not technically suitable. Leveling and smoothing was considered technically unsuitable by 25% of the respondents; 25% of them considered it costly while 25% considered it inconvenient. Dug out ponds considered were technically unfeasible by all the respondents, 75% of them reported that it was costly. All the farmers stated that there would be no cooperation from the neighboring farmers for such a venture. Waste water weirs were considered costly by 50% of the respondents; 25% reported lack of knowledge and an equal proportion considered it technically unfeasible. Deep ploughing was practised by 25% of the farmers; 50% of them considered it costly.

Crop yields and benefit-cost ratios

Soybean

Seventy-three percent of the farmers grew the Soybean JS 335 variety, 18% grew the Punjab1 variety and 9 percent grew the short duration Samrat variety. Small and marginal farmers incurred Rs 5677 ha^{-1} towards cost of cultivation with a yield of 850 kg ha^{-1}. Medium farmers and large farmers incurred Rs 6683 ha^{-1} and Rs 7074 ha^{-1} towards cost of cultivation with yields of 920 kg ha^{-1} and 956 kg ha^{-1}, respectively(Table 6b).

Wheat

Small farmers incurred Rs 8291 ha^{-1} towards cost of cultivation with a yield of 1680 kg ha^{-1}. Medium farmers and large farmers incurred Rs 10,098 and Rs 10,048 with yields of 2510 kg ha^{-1} and 2470 kg ha^{-1}, respectively (Table 6c).

Table 6b. Soybean yield and B-C ratio.

Small and marginal farmers			Medium farmers			Large farmers		
Crop	Yield (kg ha^{-1})	Market value	Crop	Yield (kg ha^{-1})	Market value	Crop	Yield (kg ha^{-1})	Market value
Grain	850	8500	Grain	920	9200	Grain	956	9560
Fodder	1500	600	Fodder	1700	680	Fodder	1790	716
Total value		9100			9880			10276
Cost-benefit ratio		1:1.60			1:1.48			1:1.45

Table 6c. Wheat yield and B-C ratio.

Small and marginal farmers			Medium farmers			Large farmers		
Crop	Yield (kg ha^{-1})	Market value	Crop	Yield (kg ha^{-1})	Market value	Crop	Yield (kg ha^{-1})	Market value
Grain	1680	13440	Grain	2510	20080	Grain	2470	19760
Fodder	1800	1080	Fodder	2700	1620	Fodder	2300	1500
Total value		14520			21700			21260
Cost-benefit ratio		1:1.75			1:2.15			1:2.12

Chickpea

Small and marginal farmers incurred Rs 5802 ha^{-1} towards cost of cultivation with a yield of 710 kg ha^{-1}. Medium farmers and large farmers incurred Rs 6970 ha^{-1} and Rs 7341 ha^{-1} towards cost of cultivation with yields of 790 kg ha^{-1} and 800 kg ha^{-1}, respectively(Table 6d).

Potato

Small and marginal farmers incurred Rs 19,330 per ha^{-1} towards cost of cultivation with a yield of 18,900 kg ha^{-1}. Medium farmers and large farmers incurred Rs 20,573 and Rs. 22,619 towards cost of cultivation with yields of 19,800 kg ha^{-1} and 21,400 kg ha^{-1} (Table 6e).

Table 6d. Chickpea yield and B-C ratio.

Small and marginal farmers			Medium farmers			Large farmers		
Crop	Yield (kg ha^{-1})	Market value	Crop	Yield (kg ha^{-1})	Market value	Crop	Yield (kg ha^{-1})	Market value
Grain	710	8520	Grain	790	9480	Grain	800	10400
Fodder	750	375	Fodder	840	420	Fodder	850	425
Total		8895			9900			10825
Cost-benefit ratio		1:1.53			1:1.42			1:1.47

Table 6e. Potato yield and B-C ratio.

Small and marginal farmers			Medium farmers			Large farmers		
Crop	Yield (kg ha^{-1})	Market value	Crop	Yield (kg ha^{-1})	Market value	Crop	Yield (kg ha^{-1})	Market value
Grain	18900	50085	Grain	19800	52470	Grain	21400	56710
Fodder	Nil	Nil	Fodder	Nil	Nil	Fodder	Nil	Nil
Cost-benefit ratio		1:2.59			1:2.55			1:2.51

Constraints to production practices

Technology – constraints

Low germination of the seeds was reported as a constraint by more than 25% of the farmers. Lack of local availability of the improved varieties of seeds was reported as a constraint by more than 40% of the farmers. These problems reflected the prevalence of weak systems of local seed storage by the farmers and lack of supply in the private markets and the public seed systems (Table 7a).

Table 7a. Constraints to production practices pertaining to technology: seed and seed treatment.

Sl. no.	Particulars	Small (48)	Medium (12)	Large (4)
1	Low germination	33	33	25
2	Low purity	19	18	25
3	Uneven germination because of uncontrolled depth	19	25	25
4	Late sowing because of unavailability of seed in time	10	17	25
5	Complete immunity not ensured by seed treatment	12	8	25
6	Lack of local supply of improved seed	39	42	50
7	Lack of knowledge about sowing methods	10	8	Nil
8	Unavailability of recommended variety	39	42	75

Water management

More than 75% of the respondents lacked any irrigation facility, with more than 50% holding the opinion that alternative irrigation was not possible. All the respondents reported that the declining water table was a major constraint (Table 7b).

Table 7b. Constraints to production practices pertaining to water management.

Sl. no.	Particulars	Small (48)	Medium (12)	Large (4)
1	Lack of irrigation	75	75	100
2	Undulating land	19	8	Nil
3	Lack of knowledge about irrigation methods and time	12	17	25
4	Alternative irrigation is not possible	75	50	50
5	Defective land shaping	39	25	25
6	Stagnation of water in the field because of inadequate drainage system	10	8	Nil
7	Declining water table	100	100	100

Fertilizer and manure management

According to most of the respondents, high application rates of fertilizers was resulting in increased diseases and pest attack. A possible reason for higher application of fertilizers was the lack of availability of FYM, which was reported as a constraint by more than 80% of the farmers (Table 7c).

Table 7c. Constraints to production practices pertaining to fertilizer and manure management.

Sl. no.	Particulars	Small (48)	Medium (12)	Large (4)
1	Judicious balancing with recommended phosphatic and potassic fertilizer is not necessary for the respective soils	17	8	25
2	High doses of fertilizer spoils the soils	83	75	75
3	Induction of more diseases and pests through application of fertilizers	62	42	50
4	Fertilizers application is more expensive	92	58	50
5	Loss of fertilizer through leaching and runoff	42	42	25
6	Poor soil conditions	44	17	25
7	Lack of timely supply	44	50	25
8	Non availability of FYM	81	92	75
9	Poor quality of FYM	50	42	50
10	Lack of timely supply of FYM	44	50	50
11	Poor fertilizer supply	31	17	25
12	FYM is not necessary	12	8	25

Weed control

Chemical application was not found as effective as hand weeding by more than 75% of the respondents, who also reported that their knowledge on weedicides was inadequate. However, weedicide was used as hand weeding was considered labor consuming and expensive, more in the case of medium sized farmers (42%) (Table 7d).

Disease and pest control

Most of the respondents felt that spraying was not effective and lack of knowledge and availability of plant protection material was a major constraint, especially according to small farmers. More than 65% of the respondents feel that the pests and diseases are not under control and chemical application was considered as toxic to animals and humans (Table 7e).

Table 7d. Constraints to production practices pertaining to weed control (% of sample per group).

Sl. no.	Particulars	Small (48)	Medium (12)	Large (4)
1	Chemical application not effective as hand weeding	81	75	75
2	Difficulty weeding in irrigated field	27	25	25
3	Weedicide cause toxicity to crop	27	17	Nil
4	Hand weeding time and labor consuming thus expensive	33	42	25
5	High cost of weedicides	81	33	50
6	Inadequate knowledge of weedicide use	77	75	75

Sl. no.	Particulars	Small (48)	Medium (12)	Large (4)
1	Spraying is not effective	19	17	25
2	Most the disease/pest are not under control	67	83	75
3	Lack of supply of plant protection material	73	58	50
4	Capital insufficient	81	67	50
5	Lack of knowledge about plant protection	81	50	25
6	Lack of local supply	81	75	75
7	Chemical are more toxic to animal and humans	77	67	25
8	No problem of disease and pests in the field	10	8	25

Table 7e. Constraints to production practices pertaining to disease and pest control (% of sample in each group).

Credit

Credit availability was a general constraint to all the respondents. The interest rate was also high with variation from one organization to another (institutional credit market vis-à-vis local credit markets with very high rates of interest, normally around 36%). The transactions costs in obtaining a loan and the recovery procedures were considered a major constraint in accessing institutional credit markets (Table 7f).

Table 7f. Constraints to production practices pertaining to credit (% of sample in each group).

Sl. no.	Particulars	Small (48)	Medium (12)	Large (4)
1	Not available from one agency and in time	100	100	100
2	Rate of interest is high but varies from agency to agency	81	75	75
3	Complicated loan procedure	81	75	50
4	Recovery procedure is stringent	67	50	50
5	The various fees, charges and costs involved in running credit agencies are very high	77	50	25

Marketing

Lack of bargaining power which results in lesser realization through the sale of the output was perceived by the respondents as a major problem. This was especially the perception of the small and medium sized farmers (73% and 67%), respectively (Table 7g).

Table 7g. Constraints to production practices pertaining to marketing (% of sample in each group).

Sl. no.	Particulars	Small (48)	Medium (12)	Large (4)
1	Monopoly and forced marketing in grain market/ vegetable market	73	67	50
2	Late and inadequate returns in market	77	75	75
3	Market located at a distant place	67	58	50
4	High transportation charges	77	50	25
5	Unauthorized charges	33	25	25

Extension

The extension support from the agriculture department and the university was not found satisfactory with more than 50% of the respondents finding it 'inadequate' (Table 7h). It was felt that the local youth were not provided with the required technical information. The trainings were conducted at distant places which were perceived as a constraint.

Table 7h. Constraints to production practices pertaining to extension support (% of sample in each group).

Sl. no.	Particulars	Small (48)	Medium (12)	Large (4)
1	Farmers training conducted at distant place	81	75	75
2	Improved production techniques are not demonstrated in the field	33	25	25
3	Intensive contact of subject matter specialists from university and agriculture department is low	67	50	50
4	Key information and important technical information are not provided to village youth	77	75	75

Summary and Conclusion

The small and marginal farmers possess higher percentage of upland where generally the soil quality is poorer (32%). Among the small landholders, 81% of the land is unirrigated when compared to 75% among the medium size farmers and 50% among the larger farmers.

All the farmers are of the opinion that the groundwater level is going down (data required on the groundwater depth, depth of the water availability from sample wells, borewells).

The intensity of input application is lower in the case of smaller farmers compared to the medium and large farmers and the intensity of medium farmers is lower when compared to large farmers. The intensity of fertilizer and FYM application is high among large farmers. The yields of all the crops also reflect that the productivity is lower in the case of the farmers who had lower inputs costs. The reasons for lesser input application are risk aversion strategy, lower area under irrigation and higher proportion of land in the upland combined with higher proportion of poorer quality soil (sandy and loamy constitute 41% in the case of small and marginal farmers).

As far as adoption of SWC measures are concerned, there is no practice of keyline cultivation, waterways, dugout ponds and waste water weirs among all the farmers. The reasons for non-adoption reported by farmer are lack of knowledge, poor technical suitability and lack of cooperation among the farmers. On an average, 76% of the farmers practice leveling and smoothing operation in at least one of their plots.

Tad Fa Watershed, Khon Kaen Province, Northeast Thailand

Somchai Tongpoonpol, Arun Pongkanchana, Pranee Srihaban and TJ Rego

Introduction

Agriculture is the main occupation in Thailand and it plays an important role in the economic development of the country. Thailand is located in the tropical monsoon climate region where the amount of rainfall is high, but shortage of water occurs even in the rainy season. Only 20 percent of the total agricultural area is under irrigation. The rest constituting rainfed area has relatively lower crop yields. The rainfed area faces the problem of soil erosion and reduced soil productivity.

The northeastern part of Thailand occupies one-third of whole country. The climate of the region is drier than that of the other regions. Most of the soils in northeast Thailand are infertile at present and liable to be further degraded. The empirical evidence shows that the yield of crops is found to decrease year by year after the conversion of the area as agricultural land because of deforestation. The infertility of the soils has been caused by improper soil management. The soils are low in fertility, have low water holding capacity (WHC), and soil erosion is a perennial problem. The interventions by ICRISAT project address these problems in the rainfed areas of northeast Thailand. The watershed area in Phu Pa Man district in Khon Kaen province has been selected as benchmark site to address the above problems and increase agricultural productivity through a sustainable manner by adopting integrated soil, water, and nutrient management (SWNM) and integrated crop management options.

Physical resources

Location and extent

Northeast Thailand is situated between 14^0 to 19^0 N latitude and 101^0 to 106^0 E longitudes. The area is about 17 million ha (one-third of the whole country) and is spread over 19 provinces, which are Kalasin, Khon Kaen, Chaiyaphum, Ysothon, Nakhon Phanom, Nakhon Ratchasima, Burirum, Maha Sarakham, Roi Et, Loei, Sri Sa Ket, Sakon Nakon, Surin, Nong Khai, Udon Thani, Ubon Ratchathani, Mukdaharn, Nong Bua Lam Phu and Amnat Charoen.

The topography of northeast Thailand is generally characterized by high plateau with the ranges of Phetchabun and Dong Phayayen in the west, Phaya Dong Rak bordering Thailand with Cambodia in the south and southeast, and Mae Khong river bordering with the Democratic Republic of Laos (LAOSPPR) in the north. In the middle, the range of Pu Pan divides the watershed area into 2 basins – Sakhon Nakhon basin on the upper part and Mun watershed on the lower part (Figure 1).

Despite receiving same amount of rainfall, northeast Thailand is drier than north and central Thailand because of the shorter rainy season. Farming is the main occupation, with only 20 percent of the total agricultural area under irrigation. The productivity is low with the farmers facing problems of soil salinity and soil erosion.

Topography

Northeast Thailand, or the “Khorat Plateau” is characterized by shallow basin (saucer-shaped basin). The plateau consists of flat-topped mountains and dissected peneplain surface with undulating features. The elevation varies from 200 meters to 1000 meters above mean sea level (msl).

Figure 1. Location of the watershed.

Geologically, the region can be divided into 6 parts.

Western highland

This area is distinct by hilly to mountainous topography, except the area close to northeastern part which is undulating to rolling topography. It covers the province of Loei and some parts of Udon Thani, Khon Kaen, Chaiyapum and Nakhon Ratchasima.

Northern highland

This area is formed as thin strip on the northernmost region. The topography is rolling to hills underlaid by lower and middle Khorat group. It covers some part of Nongkhai province and Nakhon Panom province.

Sakhon Nakhon basin

This basin is in the north of the region where Sakhon Nakhon province is located in the middle. The basin covers the provinces of Nakhon Panom, Sakhon Nakhon, Udon Thani and Nongkhai. The topography is flat to undulating underneath by evaparite-bearing salt formation. The area is approximately 43,000 sq km, and the streams mainly flow to Nong Han, the biggest lagoon in Thailand with 170 sq km size, and then flow to Maekhong river via Num Karn stream. Moreover, Songkram river originating in the north joins with Mae Lhong river flowing through the northeastern part of the plateau.

Central highland

This area is characterized by rolling to hilly topography. The range of Phu Pan is situated in southeastern part with lower and middle Khorat group underneath. Phu Pan range is extended to Maekhong river.

Khorat basin

The basin is located in the south of the region where Roi Et province and the north of Nakhon Ratchasima province are in the middle. It also covers the province of Surin, Sri Saket, Nakhon

Ratchasima, Ubon Ratchatani, Roi Et, Burirum, Mahasarakam, Chaiyapum, Yasothon, Khon Kaen and Kalasin. The topography is flat or almost flat or undulating. The area is about 137,000 sq km. The basin receives water from Mun river which originates in the southeastward mountain and flowing from the east to the south. The watershed area is about 82,000 sq km. Chi river originated in the rim of the western plateau, and flows to the middle of the basin joining the Mun in Ubon Ratchthani province of the plateau. The Chi then flows to the Maekhong in the southeast. Chi watershed is approximately 55,000 sq km.

Southern lowland

This area is situated in the southernmost region, where Panom Dong Rak range is formed as a strip. The topography is sloped northward towards Mun river and characterized by flat to undulating with some hilly topography in many areas especially the province of Surin Burirum and the southeast of Nakhon Ratchasima province. The basalt rock in tertiary area is lying underneath. From the above characterization, northeast Thailand can be described in 3 areas (ie, highland, upland and lowland).

Climate

Northeastern Thailand is located on the low latitude and is influenced by tropical low-rainfall climate and wet-dry monsoon or tropical Savannah climate. During November to February, the area is influenced by the northeast monsoon from the Eurasian continent resulting in a cooler and dry weather and covering the whole region. The southwest monsoon during May to September brings in warm and moist weather from Indian Ocean. There are three seasons in a year.

Rainy season

The rainy season starts in May or in the beginning of June and lasts into the beginning of October because of the effect of southwest monsoon. The rainfall owing to the southwest monsoon is lower than the rainfall caused by depression from the South China sea, because the ranges of Phetchabun in the northeast and Dong Phayayen in the west, and the ranges of San Khampaeng and Phanom Dong Rak in the south are the barriers.

Winter season

The winter season begins in mid-October and lasts into mid-February. This is caused by the northeast monsoon from China which brings a cool and dry climatic mass without vapor to the area. Thus the weather is very cool in the north and warm in the south.

Hot season

The hot season begins in February and lasts until the end of May. It is caused by the northeast monsoon from the South China sea and the gulf of Thailand. Because the northeast is located far away from the gulf of Thailand, the climate is hot and very dry in the region. The summary of climatological parameters of many stations in northeast Thailand during 1988–1997 is given in Table 1.

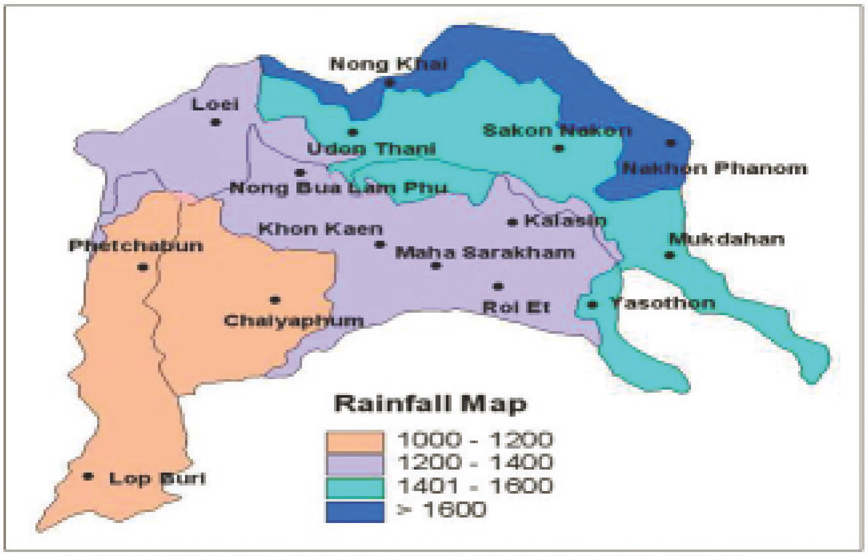
Rainfall

The rainfall in the northeast Thailand is about 1375 mm per year. The rainfall in the west and in the middle of the region such as Chaiyapum, Nakhon Ratchasima, Loei, Khon Kaen and Roi Et province is

Table 1. Mean annual rainfall (mm) in the northeast Thailand during the year 1988–1997.

Province	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Average
Mukdahan	1206	1537	1762	1515	1438	1324	1490	1370	1751	1423	1482
Sakon Nakon	1623	1569	2078	1563	1513	1369	1686	1321	1614	1588	1593
Nong Khai	1878	1822	1566	1932	1626	1723	1992	1591	1372	1749	1755
Loei	1490	1131	1357	1252	1098	862	1318	1420	1289	969	1219
Udon Thaani	1516	1399	1674	1281	1208	983	1932	1355	1845	1429	1462
Ubon Ratchathani	1270	1382	1734	1490	1597	1029	1956	1266	1470	1555	1475
Nong Bua Lam Phu	-	952	1041	457	-	865	1196	1344	1310	911	1009
Amnateharoen	1329	1595	1808	1724	1561	1167	1210	1038	1361	1306	1410
Chaiyaphum	1260	905	1193	1135	987	1026	1191	1147	1442	760	1104
Kalasin	1302	1022	1299	1361	1109	1087	1174	1023	889	1044	1131
Maha Sarakham	988	1011	1207	1381	1122	-	-	1374	1590	-	1382
Yasothon	1482	1253	1313	1345	1236	1152	1155	1203	1132	1195	1247
Nakhon Rarchasima	1446	974	914	8732	1039	1232	774	1292	1174	624	1034
Sri Sa Ket	1435	1135	1877	1387	1419	1187	1547	1448	1647	1489	1457
Khon Kaen	1255	1280	1449	1333	912	873	1252	1479	1293	898	1202
Roi Et	1477	1251	1351	1309	1257	957	1004	1194	1110	1197	1211
Nakhon Phanom	1977	2060	2975	2158	1920	2355	2326	1193	2371	2660	2324
Buriram	1360	1213	1314	1395	-	1260	-	2442	1269	-	1244
Surin	1422	1343	1567	1411	1041	1107	1439	895	1711	1480	1379

lower than the rainfall in the east and the north which is about 1000–1400 mm. The rainy days are about 108. In the eastern and northern regions such as Nakhon Panom, Sakhon Nokhon, Nong Khai, Ubon Ratchatani, Udonthani and Mukdahan province, the annual rainfall is about 1500–2300 mm. There are 123 rainy days (Figure 2).

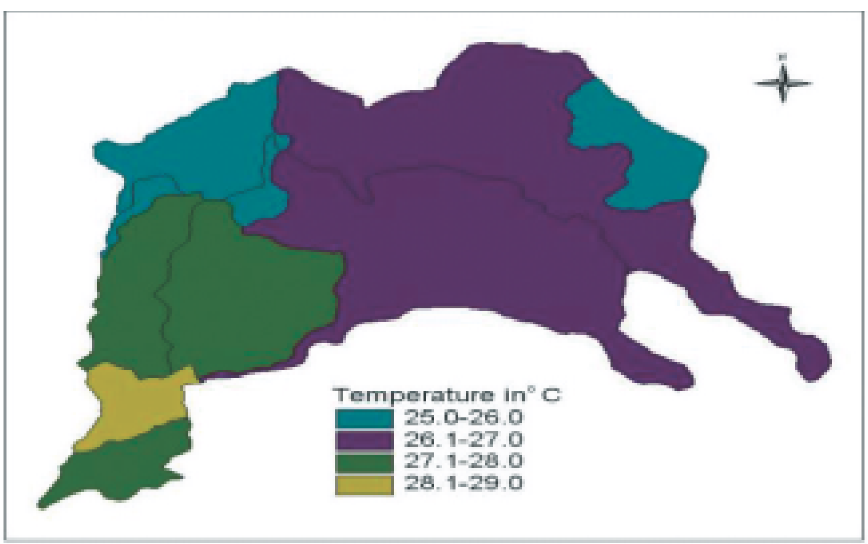


Source: Land Development department Soil and water Conservation Division

Figure 2. Rainfall distribution in the watershed.

Temperature

The mean temperature in northeast Thailand is about 26.7^{0}C. Hot season starts in March and lasts into May and winter starts in November and lasts into February. Maximum temperature is 27.4^{0}C in Nakhon Ratchasima province, and 25.7^{0}C in Sakhon Nakhon (Figure 3).



Source: Land Development department Soil and water Conservation Division

Figure 3. Temperature distribution in the watershed.

Irrigated area and water resources

The water resource in the northeast is surface water. The area consists of 2 basins – Khorat basin and Sakhon Nakhon basin. The range of Phu Pan is the barrier between these basins.

Water resources in Sakhon Nakhon basin

The Sakhon Nakhon basin is made of Nongkhai, Sakhon Nakhon and Nakhon Panom province. The streams flow to the north and then to the east, finally joining the Mekong river. Song Khram is an important river. It originates in Phu Pan range and flows through the province of Sakhon Nakhon, Nongkhai and joins with the Mae Khong in Nakhon Panom province. The other river is Huai Luang. It joins the Song Khram river in Nakhon Panom province and then flows to the Maekhong. There are many more streams such as Num Pung flowing to the Nong Han in Sakhon Nakhon province.

Water resources in Khorat basin

The basin is located in the south of Phu Pan range or in the north of the provinces of Khon Kaen, Kalasin, Nakhon Ratchasima, Maha Sarakham, Roi Et, Yasothon and Ubon Ratchathani. The important rivers are Chi and Mun. Mun river originates in the ranges of the southeast. It flows eastwards through the provinces of Nakhon Ratchasima, Burirum, Surin, Sri Sa Ket to the Maekhong in Ubon Ratchathani province. Its tributaries are made of Lum Ta Khong, Lum Pra Pleong, Lum Plai Mat, Lum Dom Yai, Lum Dom Noi etc.

Chi river originates in the ranges of the provinces of Loei, Chaiyapum and Khon Kaen. There are three main tributaries joining the Chi river. They are Num Pang originating in Loei province, Num Proom originating in Chaiyapum province and Num Pao or Lum Pao originating in Kalasin. These rivers join the Chi river at Koengnai and Warinchumrap district in Ubon Ratchathani province, and then flows to the Maekhong in the east. Lum Se, Huai Se Bok and Lum Num young are some tributaries of Chi river. The streams in the northeast normally have water only during some periods of the year and there is water shortage during the dry season, even in the main rivers such as Chi, Mun and Song Khram. Water resources development is being promoted in approximately 4.64 million ha or about 20 percent of the agricultural land.

Soil

The northeastern Thailand soils consists of 9 sub-orders – Usterts, Aquepts, Tropepts, Ustolis, Aqualfs, Ustalfs, Aquults, Ustults and Udults (Figure 4). The soil is characterized by sandy or sandy loam to sandy clay loam texture with low to medium fertility. Ustults is the largest one and mainly used for field crops (ADRC 1989). Aquults is less than Ustults, which is flat and mainly used for paddy rice (Figure 4).

Land use

The three kinds of forests are described below.

Dry dipterocarp forest

Dry dipterocarp forest exists in this region both in the flat plains and in the highlands. These forests are located in the elevated area, but below 1000 meters above msl. It is characterized by sandy or lateritic soil. This area is dry with low soil productivity.

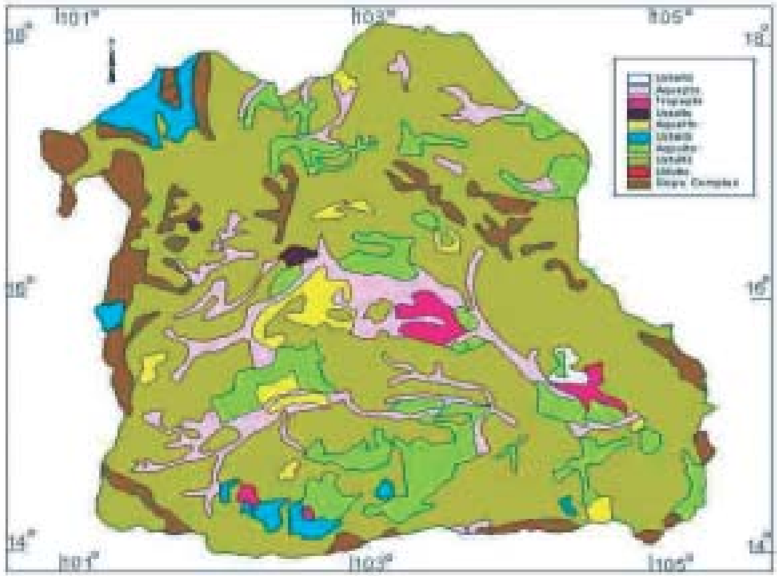


Figure 4. Soil distribution in northeastern Thailand.

Mixed deciduous forest

The mixed deciduous forest is composed of medium-size trees. These forest types are found more in the provinces of Khon Kaen, Nong Khai and Nakhon Panom.

Tropical rain forest

Large trees with high rainfall characterize the forests. Most of the area has been deforested and a greater proportion of the remaining area is in the provinces of Loei and Nakhon Ratchanima.

Physical characteristics of the watershed

The Tad Fa watershed is located within the three main watersheds, namely, subsystem of Mae Khong watershed in the northeast, Chi watershed in the east and Pasak watershed in the southwest. The biophysical and socioeconomic data were collected so as to analyze the ecological type of the watershed. The related parameters of ecoregional database comprised the rainfall, evaporation, temperature, elevation, soil and land use.

The existing data concerning the biophysical and sociological data were analyzed to present the important data in terms of watershed name, watershed code, location, latitude, longitude, area, length of main river, highest elevation, geomorphology, dam/reservoir, annual rainfall, runoff, population, province and land use, which were the main characteristics of the whole watershed as shown in Tables 2,3 and 4.

The ecoregional data

Rainfall

The rainfall data collected by the Department of Meteorology were selected during the year 1988–1997 (10 years). The average annual rainfall of the three main watersheds were analyzed based on the rainfall data within the area of those three watersheds.

Table 2. Basic data of the Mae Khong sub-watershed.			
Name: Mae Khong River Location: Northeastern region		Watershed Code: 02 Latitude: 16^{0} 08' 55 – 18^{0} 28' 00 N.Longitude: 100^{0} 54' 10 – 106^{0} 04' 00 E.	
Area: 47,002 sq km		Length of Main river: 3927 km	
Head watershed: Nammailoei		Highest elevation:	
Lower watershed: South China Sea		Lowest elevation: 130 m	
Geomorphology: Granite and Granodiolite, Kaeng Krachan Formation, Kanchanaburi Formation, Mafic and Ultramaific, Phu Phan & Phra Wihan Formation, Ratburi Formation, Mae Moh & Li Formation, Phu Kradung Formation, Alluvium, Marine Formation, Granite, Basalts and its equivalents, Phu Phan and Whian Formation salt and Khok Kruat Formation			
Watershed name	Area (sq km)	Watershed name	Area (sq km)
Second part of Nam Khong	508	Upper Part of Songkhram river	3299
Third part of Nam Khong	674	Lower part of Songkhram river	3030
Nam Un	622	Hui Klong	693
Nam Sai	876	Hui he	715
Fourth part of Nam Khong	808	Nam Yam	1733
Nam Puan	658	Hui Nam Un	3469
Lower Loei river	2902	Hui Tuay	788
Fifth part of Nam Khong	1823	Eight part of Nam Khong	1186
Nam Sano	1056	Nam Phung	971
Nam Mong	2718	Nam Kam	2537
Sixth part of Nam Khong	540	Ninth part of Nam Khong	6444
Nam sui	1310	Hui Bangsai	1366
Hui Luang	3425	Hui Muk	552
Hui Dan	681	Hui Bung Ae	1590
Seventh part of Nam Khong	2704	Lower part of Nam Khong	3387
Important Dam/Reservoir: Nam Un dam 477 m.cu.m. (1974), Hui Luang Dam 108 m.cu.m. (1973)			
Mean annual rainfall: 1871 mm. (1952–1996) at station 03023301 Amphur Mung, Sakonnakhon province			
Runoff: 36.82 cu.m/sec. (1984–1997) Ban Ta Hui Lua, Ban Muang district, Sake Nakhon provience			
Population: 5,763,690 (1997)		Province involved: Loei, Nongkhai, Udon Thani, Sakon Nakhon, Nakhon Phanom, Mudahan, Amnat Charoen and Ubon Ratchathani	
Land use: Forest 2.7%; Paddy 38.6%; Upland crop 23.5%; Fruit crops and perennial crops 5.1%; Urban 1.4%; and Water area 2.8%			

Table 3. Basic data of the Chi watershed.			
Name: Chi River		Watershed Code: 04	
Location: Northeastern region		Latitude: 15^0 30’ 00 – 17^0 30’ 00 N.	
		Longitude: 101^0 30’ 00 – 104^0 30’ 00 E.	
Area: 49,476 sq km		Length of Main river: 3015	
Head watershed:		Highest elevation:	
Lower watershed:		Lowest elevation:	
Geomorphology: Kanchanaburi Formation, Phu Phan & Pha Wihan Formation, Ratburi Formation, Phu Kradung Formation, Alluvium, Salt and Krat Formation.			
Watershed name	Area (sq km)	Watershed name	Area (sq km)
Upper Chi	2489	Nam Prom	2320
Lam Sapung	758	Nam Chern Chirn	2922
Kamkrajan	886	Lowerpart of Nam Phong	3286
Lam kanshu	1635	Hui Saibath	741
Second part of Nam Chi	3808	Fourth part of Nam Chi	4510
Hui Sammo	729	Upper part of Lam Pao	3282
Third part of Nam Chi	3244	Lampanchard	657
Upper part of Nam Phong	4424	Lower part of Lam Pao	4264
Hui Pui	916	Nam Yang	4145
Lampaneang	1912	Lower part of Nam Chi	2548
Important Dam/Reservior: Ubolratana 1,854 m.cu.m (Constructed in 1996) Chulaporn (144 m.cu.m 1972) Nam Pung (156 m.cu.m 1965) Lam Pae (135 m.cu.m 1968)			
Mean Rainfall: 1842 mm. (1952–1996) at station 0140801 Amphur Muang, Khon Kaen province 1131 mm. (1952–1996) at station 01041607 Amphur Kosum pisai, Mahasarakam province			
Runoff: 122.0 cu.m/sec. (1952-1996) at station 01041601 Wat Thai Kosum Amphur Kosum pisai, Mahasarakam province			
Population: 6,709,329 (1998)		Province involved: Chaiyaphum, Nakon Ratchasima, Khon Kaen, Loei, Udon thani, Nong Bua Lam Phu, Maha Sarakham, Roiet, Kalasin, Yasothon, Ubon Ratchathani	
Land Use: Forest 22.2%; Paddy 47.5%; Upland crops 23.5%; Fruit crops and perennial crops 0.2%; Urban 1.4%; Water area 2.8%; Swamp and Natural grassland 2.4%.			

- Mae Khong watershed; data were from the provinces, namely, Loei, Nong Khai, Sakon Nakhon, Nakhon Phanom, Mukdahan and Amnat charoen.
- Chi watershed; data were from the provinces, namely, Udon Thani, Khon Kaen, Nong Bua Lam Phu, Chayaphum, Kalasin, Maha Sarakham, Yasothon, Nakhon Ratchsima, Si Sa Ket, Roi Et and Ubon Ratchathani.
- Pasak watershed; data were from the provinces, namely, Phetchabun, Lop Buri and Saraburi.

Table 4. Basic data of the Pasak watershed.			
Name: Pasak River Location: Eastern region Area: 15,799 sq km Head watershed: Phetchabum Lower watershed: Mae Nam Chao Praya		Watershed Code: 12 Latitude: 14^{0} 21’ 44 – 17^{0} 16’ 02 N. Longitude: 100^{0} 34’ 40 – 104^{0} 104’ 56 E. Length of Main river: 1039 Highest elevation: Dan Sai, Loei province Lowest elevation: Uthai, Phra Nakhon, Si Ayuthaya	
Geomorphology: Phu Kradung, Phu Phan and Phra Wihan Formation, Ratburi Formation, Marine Formation, Andesite-Rhyorite, Basalt and its equivalents, Granite, Diorite and quartz diorite			
Watershed name	Area (sq km)	Watershed name	Area (sq km)
Upper part of Nam Pasak	1465	Hui Kokaew	520
Hui Nam Phu	655	Lam sonti	1410
Second part of Nam Pasak	2205	Lower part of Nam Pasak	4152
Third part of Nam Pasak	4717	Hui Muak lek	655
Important Dam/Reservoir: Pasak Chonlasit dam 746 m.cu.m. (Constructed in 1999)			
Mean Annual Rainfall: 1,180 mm (1952–1996) at station 03120505 Wichian Buri, Phetchabun province			
Runoff: 76.70 cu.m./sec. (1956–1996) at station 0112806 Kaeng Khoi, Saraburi province			
Population: 1,785,424 (1998)		Province involved: Phetchabum, Lop Buri, Saraburi and Phra Nakhon Si Ayuthaya	
Land use: Forest 19.4 %; Passy 19.5%; Upland crop 47.6%; Fruit crop and Perennial crop 2.6%; Urban 2.0%; Water area 0.82%; Swamp and natural grassland 8.7% (1998)			

Evaporation

The evaporation data collected by the Department of Meteorology were selected during the year 1988–1997 (10 years). The average annual evaporation of the three main watersheds were analyzed based on evaporation data within the area of those three watersheds.

- Mae Khong watershed; data were from the provinces namely Loei, Nong Khai, Sakon Nakhon, Nakhon, Phanom, Mukdahan and Amnat charoen.
- Chi watershed; data were from the provinces namely Udon Thani, Khon Kaen, Nong Bua Lam Phu, Chayaphum, Kalasin, Maha Sarakham, Yasothon, Nakhon Ratchasima, Sri Sa Ket, Roi Et and Ubon Ratchathani.
- Pasak watershed; data were from the provinces namely Phetchabun, Lop Buri and Saraburi (Figure 5).

Temperature

The temperature data collected by the Department of Meteorology were selected during the year 1988–1997 (10 years). The average annual temperatures of the three main watersheds were analyzed based on temperature data within the area of those three watersheds.

- Mae Khong watershed; data were from the provinces namely Loei, Nong Khai, Sakon Nakhon, Nakhon Phanom, Mukdahan and Amnat charoen.

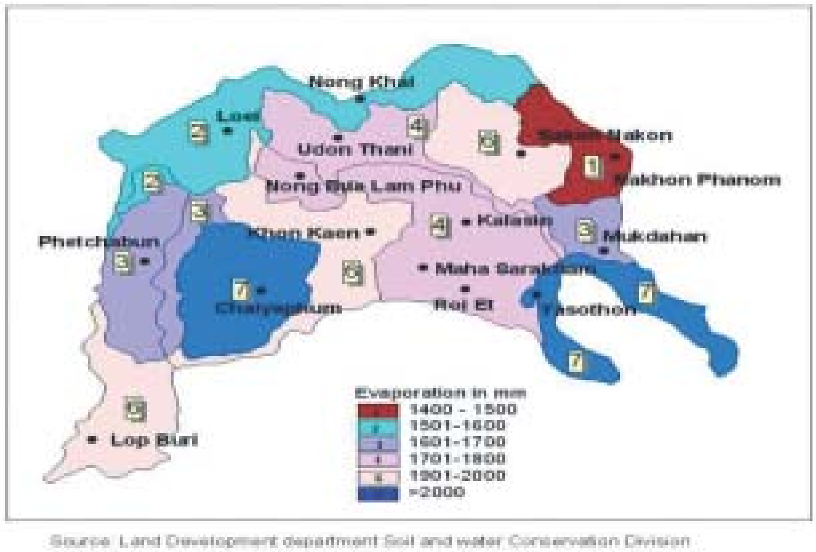


Figure 5. Evaporation map of the three watersheds: Maekhong, Chi and Pasak

- Chi watershed; data comprised the provinces, namely, Udon Thani, Khon Kaen, Nong Bua Lam, Phu, Chayaphum, Kalasin, Maha Sarakham, Yasothon, Nakhon Ratcasma, Sri Sa Ket, Roi Et and Ubon Ratchathani.
- Pasak watershed; data were from the provinces, namely, Phectchabun, Lop Buri and Saraburi.

Topography

The result of the analysis of landform and slope class map done by LDD is shown in the Figure 6.

Elevation

The contour map of the Royal Thai Survey was introduced and used as the base map for analysis of the contour interval which were grouped into 5 levels ranging from 100–200 meters, 200–500 meters, 500–1000 meters, 1000–2000 meters and more than 2000 meters.

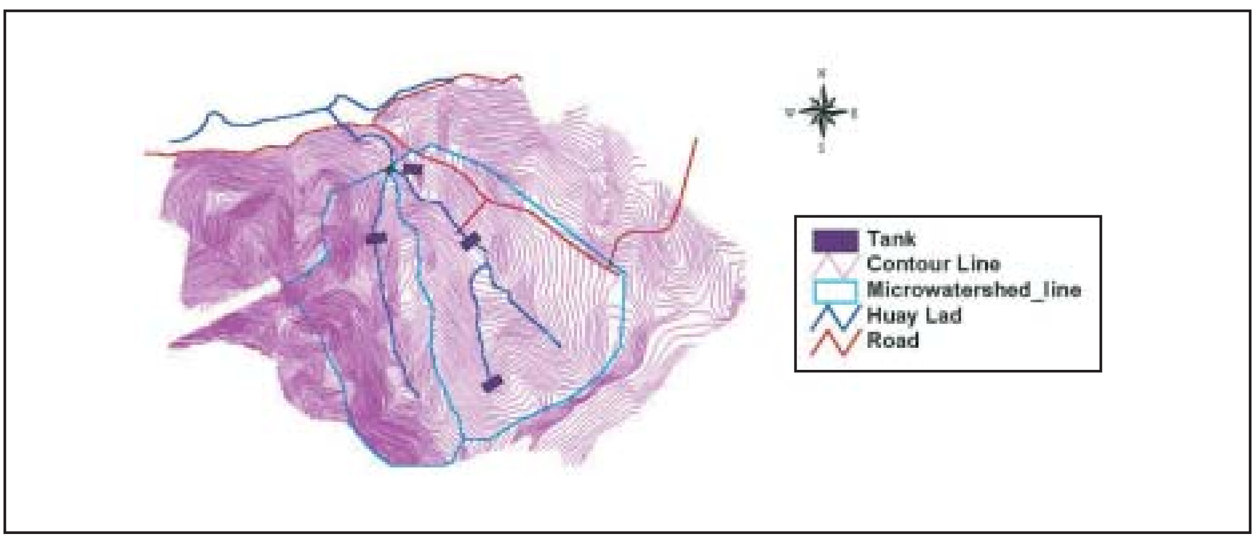


Figure 6. Topography and drainage lines map of Tad Fa micro-watershed.

Soil

The result of the soil analysis is shown in the Figure 4.

Land use

The result of the analysis of land use map done by LDD in 1998 is shown in Figure 7.

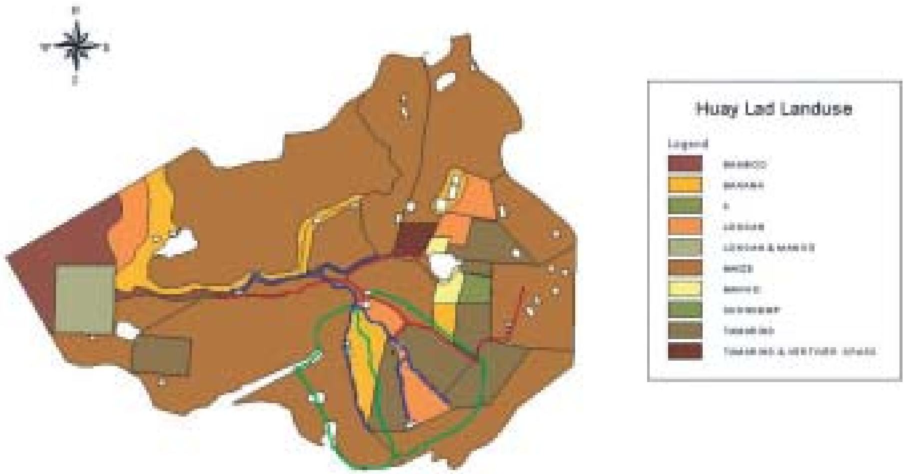


Figure 7. Land use map of Huay Lad Watershed.

Criteria approach

The following criteria were chosen to analyze and group the data.

Rainfall

The data of mean annual rainfall were grouped into 4 classes ranging 1000–1200 mm, 1201–1400 mm, 1401–1600 mm and more than 1600 mm (Table 5). Then, the areas of each interval were measured for their percent and area of the whole watershed (see Figure 2).

Evaporation

The data of mean annual evaporation were grouped into 7 classes ranging as follows (Table 6):

The areas of each class were measured for their percent and area of the whole watershed as shown in Figure 5.

Table 5. Rainfall ranges.

Rainfall (mm)	Class
1000–1200	1
1201–1400	2
1401–1600	3
>1600	4

Table 6. Evaporation classes.	
Evaporation (mm.)	Class
1400–1500	1
1501–1600	2
1601–1700	3
1701–1800	4
1801–1900	5
1901–2000	6
> 2000	7

Temperature

The data of mean annual temperature were grouped into 4 classes as shown below (Table 7) and in Figure 3.

Table 7. Temperature classes.	
Temperature	Class
25.0–26.0	1
26.1–27.0	2
27.1–28.0	3
28.1–29.0	4

Topography

The topographic maps were introduced to analyze and were subdivided into 3 levels as shown in Table 8.

Table 8. Topography classes.	
Topography	Class
Slope Complex	S
Up Land	U
Low Land	L

Hypsographic

The analyzed mean sea level was grouped into 5 classes (Table 9) as shown in Figure 8.

Table 9. Hypsographic classes.	
Hypsographic MSL	Class
100—200	1
200—500	2
500–1000	3
1000–2000	4
> 2000	5

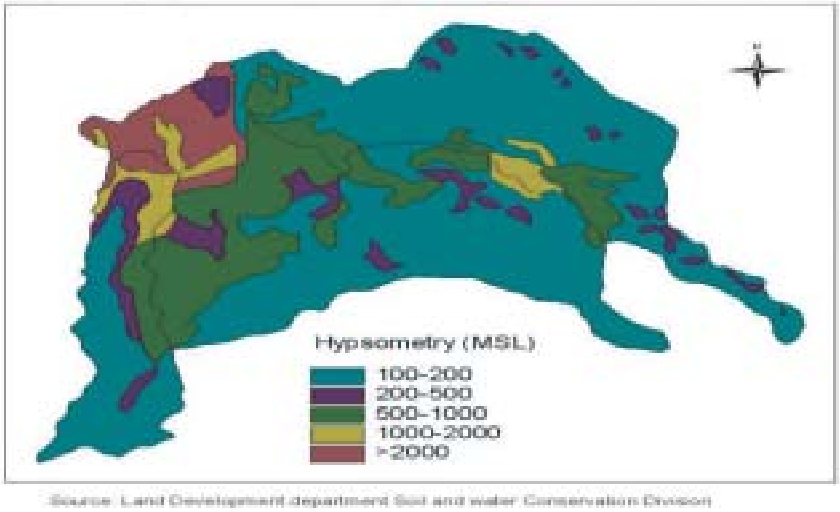


Figure 8. Hyposometry map of the three watersheds: Maekhong, Chi and Pasak.

Soil

Figure 4 shows the soil map by LDD in suborder.

Land use

The land use maps prepared by LDD in 1998 is shown in Figure 9.

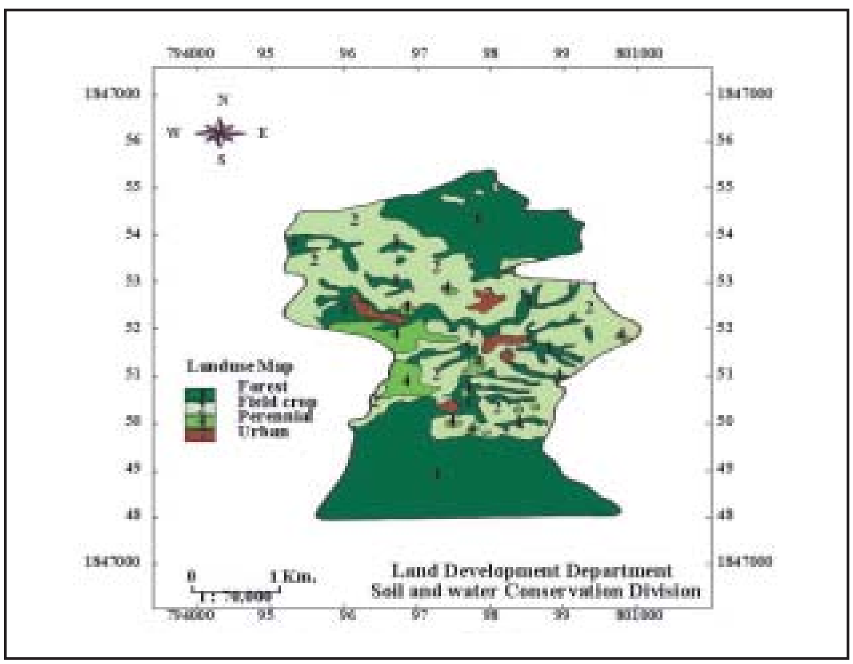


Figure 9. Land use map of Tad Fa Watershed.

Agricultural productivity – yield gap analysis in northeast Thailand

The amount of rainfall in the region was lower than in the other regions. So agriculture was based mainly on upland crops such as cassava, sugarcane, maize, upland rice, groundnut and soybean. This study was done on sustainable agriculture and emphasized on crops, which minimized the use or the destruction of natural resources and improved the soil quality. The following five crops were selected for this study – rice, maize, soybean, groundnut and sunflower.

Rice

Rice is an economically important crop to the Thai society. Since 1979, the export of rice has assumed increased importance. The total area of production and productivity are given in Table 10.

Table 10. Rice production by region in 1998.

Regions	Planted Area (rai)*	Harvested area (rai)	Production (in tons)	Yield (kg rai^{-1})
Northeastern (NE)	31,040,327	28,543,360	8,009,659	281
Northern (N)	12,526,986	11,217,283	4,975,721	444
Central Plain (C)	9,886,193	9,406,367	4,289,886	456
Southern (S)	2,919,666	2,677,407	885,449	331

* 6.25 rai = 1 ha

Yield in the northeastern was 50% lower than the yield in research plots and 11% lower than that of the whole country (Table 11). When considering the morphogeology of the northeast, yield in the highland and upland area was lower than that of the whole country and the yield was high in plain flat lands.

The upland rice was grown for household consumption. Farmers did not grow upland rice for trading, because the quality of seeds did not meet the requirement of the market. The yield of the upland rice was also 50% lower than that of the paddy field.

The upland rice yield in the northeast was 28% lower than the research plots yield and about 18% lower than the yield of the whole country (Table 12).

Table 11. Crop productivity gap in Northeast Thailand.

		Yield gap (kg rai^{-1})	
Type	Yield (kg rai^{-1})	Research plots yield	Country yield
Research plots yield (Ey)	566	-	-
Country yield (Cy)	314	252 (44%)	-
Northeastern yield (Ny)	281	285 (50%)	33 (11%)
Northeastern on highland yield (Nhy)	195	371 (65%)	199 (63%)
Northeastern on upland yield (Nuy)	289	277 (48%)	25 (7%)
Northeastern on lowland yield (Nly)	347	219 (38%)	33 (10%)

Table 12. Crop productivity gap of upland rice in the northeastern.

		Yield gap (kg rai^{-1})	
Type	Yield (kg rai^{-1})	Research plots yield	Country yield
Research plots yield (Ey)	238	-	-
Country yield (Cy)	210	28 (11%)	-
Northeastern on highland yield (Nhy)	195	43 (18%)	15 (7%)

Maize

In Thailand, maize is being grown for the last 40 years. During 1988–1992, Thai maize production had decreased by 7%, mainly because of frequent droughts during crop season. This resulted in farmers shifting to other drought resistance crops such as sugarcane and cassava. Out of a total production area of 8.8 million rais, 2.3 million rais was in the northeastern part of the country (Table 13). The yield was lower than the yield in other regions.

The corn yield of the northeast was 47% lower than the yield in the research plots, 12% lower than that of the country (Table 14). Considering morphogeology, yield in highland and upland area was lower than that of the whole country, and the yield is high in the lowland.

Soybean

In Thailand, soybean is being grown since 1936. In northern part of the country, farmers were recommended to grow soybean after rice. However, the seeds were imported from China and Japan, which were not suitable to the local conditions in Thailand. In 1960, variety improvements were undertaken and many good varieties were produced. Due to an increase in the livestock population, the requirement of soybean reached 2 million tons per year. From the total production area of 2.6 million rais, Thailand produced 0.5 million tons per year. The northeastern part of the country grew soybean in 349,613 rais (Table 15). The yield in the region was low.

Table 13. Maize production by region in 1998.

Region	Planted area (rais)	Production (tons)	Yield (kg rai^{-1})
Northeastern (NE)	2,336,920	915,476	392
Northern (N)	4,106,353	1,890,036	460
Central Plain (C)	2,278,877	1,116,075	490
Southern (S)	106,409	43,750	411

Table 14. Productivity gap of maize in the northeastern region.

Type	Yield (kg rai^{-1})	Yield gap (kg rai^{-1}) Research plots yield	Yield gap (kg rai^{-1}) Country yield
Research plots yield (Ey)	753	-	-
Country yield (Cy)	449	304 (40%)	-
Northeastern yield (Ny)	392	361 (47%)	5 7 (12%)
Northeastern on highland yield (Nhy)	244	509 (67%)	205 (45%)
Northeastern on upland yield (Nuy)	382	371 (49%)	67 (15%)
Northeastern on lowland yield (Nly)	559	194 (25%)	110 (24%)

Table 15. Soybean production by region in 1998.

Region	Planted area (Rais)	Production (tons)	Yield (kg rai^{-1})
Northeastern (NE)	349,613	71,619	192
Northern (N)	2,061,069	385,004	192
Central Plain (C)	308,196	70,247	199
Southern (S)	182	37	203

The yield in the northeastern regions was 37% lower than the yield in the research plots, 1% lower than that of the country (Table 16). Morphogeologically, the yield in the highland and upland area was lower than the yield in the whole country and the yield was higher in lowland.

Table 16. Crop productivity gap of soybean in Northeast Thailand.

Type	Yield (kg rai^{-1})	Yield gap (kg rai^{-1})	
		Research plots yield	Country yield
Research plots yield (Ey)	306	-	-
Country yield (Cy)	194	112 (36%)	-
Northeastern yield (Ny)	192	114 (37%)	2 (1%)
Northeastern on highland yield (Nhy)	156	150 (49%)	38 (19%)
Northeastern on upland yield (Nuy)	180	126 (41%)	14 (7%)
Northeastern on lowland yield (Nly)	206	100 (32%)	12 (6%)

Groundnut

Groundnut is an important crop in Thailand introduced by the Portuguese. Since 1962, the department of agriculture initiated research efforts to improve the varieties. Out of a total area of 4.5 million rais, the groundnut area in the northeast was 228,565 rais. The yield was low at 214 kg rai^{-1} (Table 17).

Table 17. Groundnut production by region in 1998.

Region	Planted area (rais)	Production (tons)	Yield (kg rai^{-1})
Northeastern (NE)	228,565	50,617	214
Northern (N)	295,850	69,919	238
Central Plain (C)	96,881	24,465	247
Southern (S)	29,375	3,169	176

The groundnut yield in the northeastern region was 23% lower than that of the research plots and 7% lower than that of the rest of the country (Table 18). Morphogeologically, the yield in the highland and upland area was lower than the yield in the whole country and it was higher in the lowland areas.

Table 18. Crop productivity gap of groundnut in the northeastern.

Type	Yield (kg rai^{-1})	Yield gap (kg rai^{-1})	
		Research plots yield	Country yield
Research plots yield (Ey)	278	-	-
Country yield (Cy)	231	47 (16%)	-
Northeastern yield (Ny)	214	64 (23%)	17 (7%)
Northeastern on highland yield (Nhy)	186	92 (33%)	45 (19%)
Northeastern on upland yield (Nuy)	211	67 (24%)	20 (9%)
Northeastern on lowland yield (Nly)	247	31 (11%)	16 (7%)

Sunflower

Sunflower, which originated in the west of the United States of America was introduced into Thailand in 1973. But it was not successful because of its low yield and marketing problems. Since 1987, extension efforts were directed to introduce it as the second crop in the central plain such as Saraburi and Lob Buri. In other areas, it is grown by a few farmers and still cannot be classified as an economic crop (Table 19).

In the northeastern region, the yield is lower than the research plots yield by 6% and 0.4% lower than that of the country as shown in Table 20.

Table 19. Sunflower production in 1993.

Region	Planted area (rais)	Production (tons)	Yield (kg rai^{-1})
Northeastern (NE)	63,500	14,980	235
Northern (N)	174,820	43,005	246
Central Plain (C)	270	64	238

Table 20. Crop productivity gap of sunflower in the northeastern Thailand.

		Yield gap (kg rai^{-1})	
Type	Yield (kg rai^{-1})	Research plots yield	Country yield
Research plots yield (Ey)	255	-	-
Country yield (Cy)	239	16(6%)	-
Northeastern on highland yield (Nhy)	238	17(6%)	1 (0.4%)

Analysis of constraints in the watershed

It was apparent that in Thailand, a few of the factors and constraints involved in agricultural productivity are nationwide. Mostly they had specific regional or provincial relevance. Constraints on productivity could be discussed under the following headings.

- Physical constraints
- Technological constraints
- Institutional constraints
- Socioeconomic constraints

Physical Constraints

Physical constraints had a major impact on agricultural productivity. The main physical constraints were

- Climatic, especially rainfall, relative humidity, and dry season temperatures
- Relief or topography
- Drainage and flood hazards
- Soils
- Accelerated erosion and runoff

Climatic constraints

The major climatic constraint was the low rainfall in dry season. A less important climatic constraint was the high relative humidity in the wet season, which encourages pest and diseases in dry-land crops such as maize and sugarcane. In the dry seasons, temperatures decreased with the increase in altitude in the mountains. Temperature restricted the range of introducing tropical perennial crops that could be grown. Although at the same time, there was a possibility of introducing temperate crops. However, the area affected by this constraint was very limited in extent and was generally lacking in agricultural potential for reasons of topography and soil.

Topographic constraints

The steep and uneven slopes made cultivation difficult and resulted in rapid runoff of rainfall, accompanied by sheet and gully erosion.

Drainage and flood constraints

Flooding was the major factor resulting from intensive rainfall in the wet season causing rivers to rise and inundate large areas of lowland crops.

Soil constraints

The major soil constraints were low fertility, affecting most highlands soils and the severely leached soils on the slightly higher terrain of the old terraces in the lowlands. The other widespread soil limitation was shallow depth, lateritic gravel aggregates and loss of applied nutrients during the wet season, especially on the steep slopes. In addition, they reduced the total water-holding capacity of the soil profile, limit-rooting depth, and increased the erosion hazard. The soil depth might be limited by bedrock or by dense and/or compacted lateritic gravels.

Erosion and runoff constraints

The increase of cultivation and illegal logging in the past decades in marginal highland areas resulted in an acceleration of soil erosion and runoff.

Technological Constraints

The physical constraints could be countered by technological measures. Such measures included irrigation, drainage flood control, system of highland agriculture and forest conservation, application of fertilizers, pesticides, weed control, improvement of seed supply and crop varieties.

Institutional Constraints

The main institutional constraints on agricultural productivity which are typically found in developing countries with inadequate research, training, extension and availability of agricultural credit, were relatively well developed in Thailand. The government operated numerous agricultural research bodies and research stations. The Department of Agricultural Extension Service was established in each province in the capital and at the district level, and provided a reasonably effective and comprehensive service to farmers. The country had many agricultural training establishments at all levels, which provided the government with competent recruits for its various agricultural departments. The institutional credit to farmers was provided by the Bank of Agriculture and Agricultural Cooperatives (BAAC), cooperatives, farmer's welfare funds and commercial banks.

Socioeconomic Constraints

Social constraints

There were a few social constraints on agricultural productivity in Thailand. The Thai farmer was capable, adaptable, owner of the land, and was generally free from restrictive government control and direction. Prior to 1975, rapid population growth was the main constraint, and subsequently, the population pressure was building up on the land. This in turn led to the expansion of agricultural activity to less suitable lands.

Economic constraints

There were a few direct economic constraints on agricultural productivity in Thailand. In addition to the widespread institutional and infrastructure support to agriculture, the government also attempted to guarantee farmer's income by imposing minimum farm-gate prices for certain crops, avoiding unnecessary restrictions on the farmers at the same time.

Analysis of the productivity constraints

The northeastern part of the country is an important agricultural area and a significant proportion of the production of important crops came from this region. But there were productivity constraints in terms of occurrence of droughts, floods and low soil fertility causing low yields. The production constraints of the lowland, upland and highland areas in the northeastern are tabulated in Tables 21, 22 and 23, respectively.

Table 21. Production constraints of the lowland in the northeastern region.

	Physical constraints		Technological constraints			Institutional constraints			Socioeconomic constraints		
Crops	Climate	Soils	Irrigation	Drainage & flood control	Fertilizers	Sustainable agriculture	Crop verities	Financial	Technology institute	Social	Economic
Rice	L	M	M	M	M	M	L	M	M	M	M
Maize	L	M	M	M	M	M	L	M	M	M	M
Soya bean	L	M	M	M	M	M	L	M	M	M	M
Mung bean	L	M	M	M	M	M	L	M	M	M	M
Sunflower	L	M	M	M	M	M	L	M	M	M	M

Level of constraint: L = Low; M = Moderate; H = High

Table 22. Production constraints of the upland in the northeastern.

	Physical constraints		Technological constraints			Institutional constraints			Socioeconomic constraints		
Crops	Climate	Soils	Irrigation	Drainage & flood control	Fertilizers	Sustainable agriculture	Crop verities	Financial	Technology institute	Social	Economic
Rice	L	M	M	M	M	M	L	M	M	M	M
Maize	L	M	M	M	M	M	L	M	M	M	M
Soya bean	L	M	M	M	M	M	L	M	M	M	M
Mung bean	L	M	M	M	M	M	L	M	M	M	M
Sunflower	L	M	M	M	M	M	L	M	M	M	M

Level of constraint: L = Low; M = Moderate; H = High

Table 23. Production constraints of the highland in the northeastern.

	Physical constraints		Technological constraints			Institutional constraints			Socioeconomic constraints		
Crops	Climate	Soils	Irrigation	Drainage & flood control	Fertilizers	Sustainable agriculture	Crop verities	Financial	Technology institute	Social	Economic
Rice	L	M	M	M	M	M	L	M	M	M	M
Maize	L	M	M	M	M	M	L	M	M	M	M
Soya bean	L	M	M	M	M	M	L	M	M	M	M
Mung bean	L	M	M	M	M	M	L	M	M	M	M
Sunflower	L	M	M	M	M	M	L	M	M	M	M

Level of constraint: L = Low; M = Moderate; H = High

Physical constraints

Climate

Thailand has a tropical climate and there is not much variation in the weather. The limitation is the occurrence of dry period during the rainy season. The climatic constraint could be classified as low.

Soil

Soils in the recent past degraded because of the degradation of the land. In the northeast Thailand, the soils in the agricultural area have been found highly degraded compared to soils in the forestry area, especially in the flat plains where there is a problem of the salt expansion. The Land Development Department (LDD 2000) reported that the salt-affected area in the northeastern with 18 million rais or about 17 percent of the region was causing a productivity constraint. So, in the Kong-Chi–Mun project, salt tolerant crops and increasing the forest area were encouraged. The LDD has a target for soil improvement using 0.25 million rais of the compost of producing and providing for seed, about 8050 tons in the area of 1.6 million rais.

Application of fertilizer

There is now an effort to move towards application of organic fertilizers because of the high cost and the polluting nature of chemical fertilizers. The Soil and Water Conservation Department carried out an experiment in 1999 about the use of compost in rice growing at Roi Et province. The yield was 23% higher than the yield using chemical fertilizers. An experiment on the use of sesbania-rostrata before rice planting showed that the yield of rice was only 3.6% lower than the use of 16-16-16 fertilizer in 20 kg rai^{-1}. The Land Development Department aims to decrease the usage of chemical fertilizers and promote the use of compost or green manure along with the promotion of soil and water conservation by the use of vetiver grass and prevention of soil erosion in 5 million rais in a year.

Improved seeds and varieties

This constraint was low as government and private sector were working actively to distribute and sell seeds to the farmers. The Department of Agriculture, in 1994, developed the following varieties: Upland rice variety named Sew Mae Jan in Khon Kaen province and its yield was found to be about 320 kg rai^{-1}; the yield of soybean, Nakosawan variety, was about 265 kg rai^{-1} and the yield of sunflower, pacific 33 variety, was about 228 kg rai^{-1}.

Credit

Farmers owning large landholdings had greater access to credit from government or commercial banks, whereas the small farmers with marginal landholdings rented out their land and had access only to the costlier loans from private moneylenders.

Agricultural research

The government has a technology transfer center in each sub-district. Therefore, there was no technological constraint in the institutional mechanism for technology transfer.

Socioeconomic constraints

There was a shortage of agricultural labor and generally the farmers with marginal landholding preferred to lease out their land. The main problem was that some crops had a minimum support price and others did not.

Recommendations for the future interventions

- Reclamation and development of the watershed to address soil erosion problem needs to be undertaken.
- The use of organic fertilizer needs to be promoted.
- There is a need to improve the Land Development Act and improve the classification of the watershed (needs to be clarified).
- There is a need for land reforms to address the problem of inequity in the landholding structure.
- Future market needs to be developed for agricultural commodities so that the farmers have a better option of getting assured and better returns.
- There is a need to develop agro-industrial enterprises.

Summary and conclusion

The constraint analysis of agriculture in the northeast Thailand reveals the existence of problems related to infertility of the soil, soil erosion and flooding because of the steep slope of the land. The increasing pressure of the population, which has lead to the conversion of forestland to agriculture land, has been a major reason for the above problem. The Department of Land Development in Thailand admits that the magnitude of the problem is large and admits that tackling the problem in its totality requires huge budgetary support, which is a constraint. To address the budgetary constraint problem and to garner greater contribution from the farmers for soil and water conservation works, there is a need to effectively demonstrate that yield increases are possible and the gaps between the potential yields in the research plots and the farmer fields need to be reduced. These differences are currently relatively high particularly for rice (50% lower), maize (47% lower), soybean (37% lower) and sunflower (6% lower).

The intervention of the project should provide the scope to demonstrate that cost-effective solutions with farmer's participation (in program conceptualization and financial support) is a possible solution. The advantage of the intervention process is the decentralized agriculture extension system in the country, which can be effectively utilized.

References

ADRC (Agricultural Development Research Center). 1989. Soil Genesis and Classification. *In* Activities and Research Highlights (1984–1988), July 1989, Agricultural Development Research Center in Northeast Thailand. Moe Din Daeng, Khon Kaen 4000, Thailand: ADRC.

LDD (Land Development Department). 2000. Yield Gap Analysis of 3 Main Watersheds in the Northeast Thailand. Project No 2: The Eco-regional Database, December 2000, Land Development Department.

Thanh Ha Watershed, Hoa Binh Province, Vietnam

NV Viet, HM Tam, NT Chinh, NV Thang and A Ramakrishna

Location

Thanh Ha watershed is located in village # 7 of the Thanh Ha State Farm. Village # 7 is under the administrative control of Phu Thanh Commune, Lac Thuy District, with revenue jurisdiction under Thanh Ha State Farm (Figure 1).

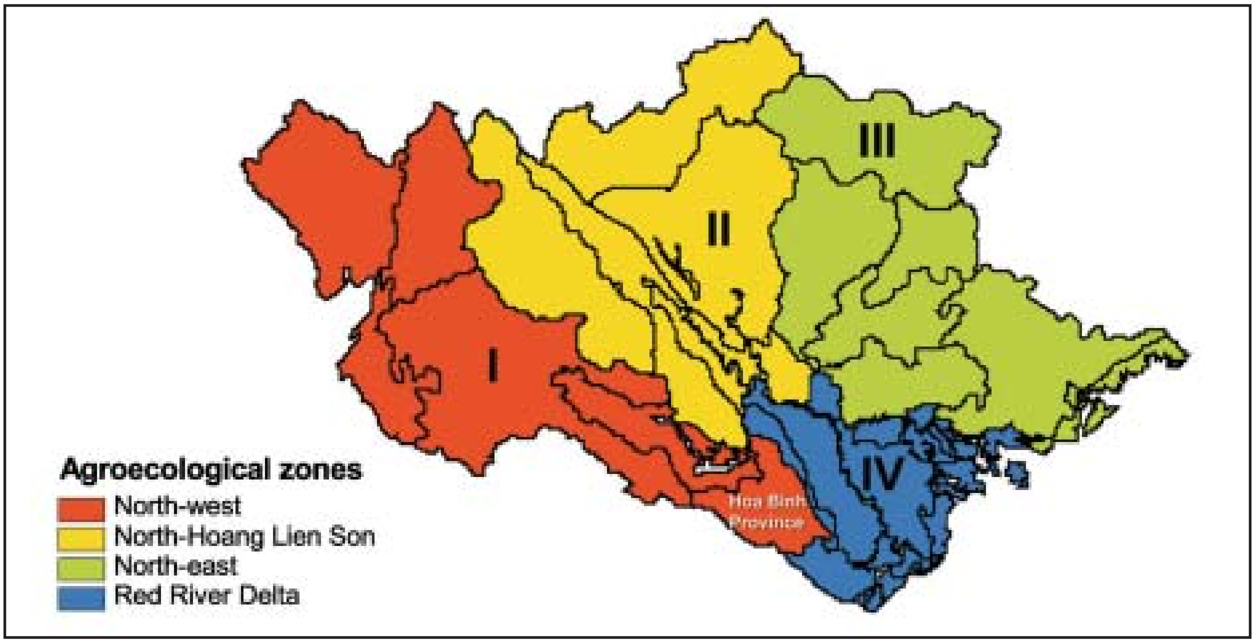


Figure 1. Location of the watershed in Brigade # 7, Thanh Ha State Farm, Hoa Binh province.

Physical and Biological Environment

Climate

The climate in the watershed (Figure 2) is monsoonal with hot, wet summers (April to August) and cool, cloudy, moist winters (December–February). The total rainfall is 1600–2000 mm per annum (Figure 3). The average annual temperature is 25^0C, with an average maximum of 35^0C (in August) and an average minimum of 12^0C (in January). The southwest monsoon occurs during May to October, bringing high temperatures and heavy rainfall. November to May is the dry season with a period of prolonged cloudiness, high humidity and light rain. The length of growing season in northern Vietnam ranges from 210 to 365 days thus providing an opportunity for cropping throughout the year in some regions (Figure 4).

Vegetation

The monsoonal tropical climate with high humidity prevailing in the rainfed sloping lands of northern Vietnam is quite favorable for forest growth and development. These are almost completely covered by the forest. At present, planted and natural forest covers only about 26%. Orange, litchi, longain, guava, papaya and custard apple are important horticultural crops while tea occupies higher altitudes.

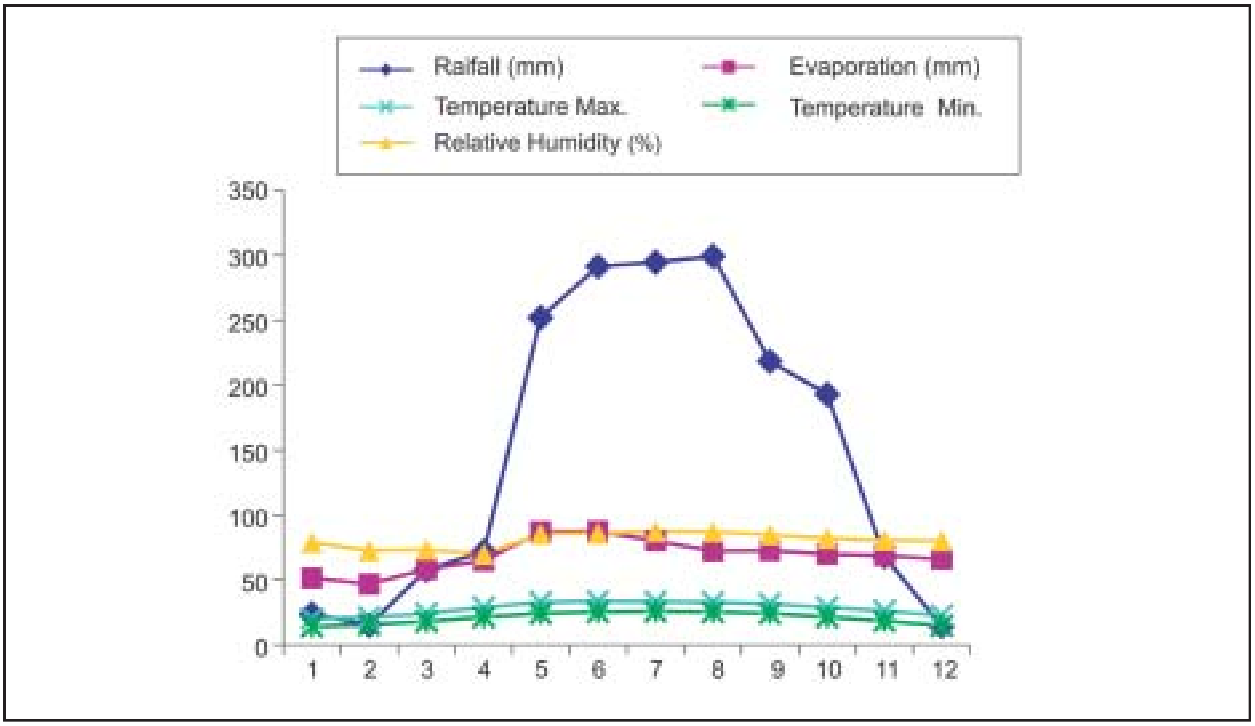


Figure 2. Climate in watershed.

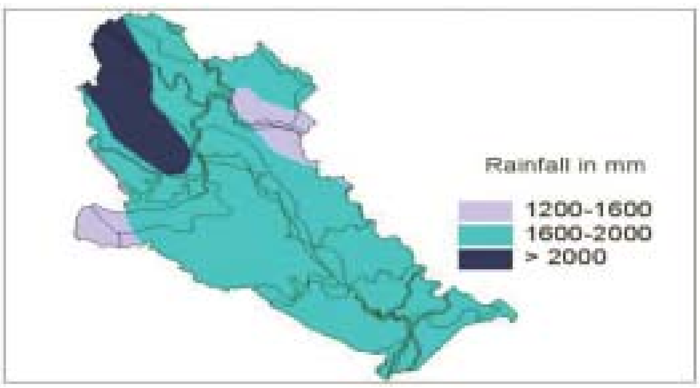


Figure 3. Rainfall at the Thanh Ha watershed.

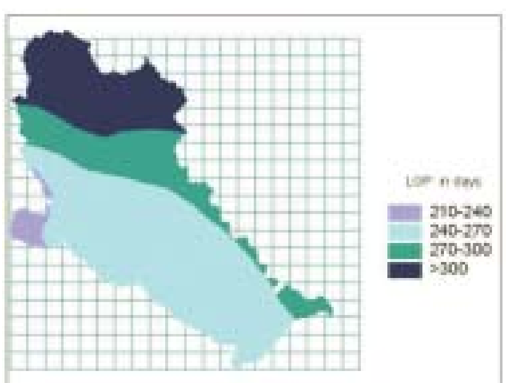


Figure 4. Length of the growing period.

Soils

Soils are complex and varied. The basic process of soil formation is ferralitic (through weathering of the parent material) leading to accumulation of rather high amounts of iron and aluminum, with leaching of silica and most base cations. The most common soil type is the red-yellow ferralitic. These soils accumulate iron and aluminum to form laterite. Mineralization is rapid, and organic substances quickly break down, resulting in low humus content. Intensive surface cultivation and deep leaching processes make the soil very acidic and poor in nutrients. Nitrogen, phosphate and cations are easily dissolved or carried away to such an extent that these soils cannot be cultivated for long before they suffer serious degradation. In extreme cases of erosion, a hardpan of laterite nodules is exposed.

Soils in the benchmark watersheds were analyzed to a depth of 1.5 m and also based on the toposequence for physical and biological properties. Soil was medium loamy in texture, acidic in nature with very poor organic matter, medium potassium and very low phosphorous (P) content. Because the soils had very low organic matter and P, they are more suitable for industrial crops (tea) and fruit crops (litchi) than annual crops (maize and legumes). Soils need organic and inorganic supplements and particularly P fertilizer for good productivity if annual crops are grown. It is better to use thermophosphate than superphosphate in these soils. Total microbial population was 10^{6}–10^{8} CFU g^{-1} including bacteria, streptomycin and fungi with highest number of bacteria. Soil was rich in microbial population with large biodiversity and had good ability to develop biological activities with cultivation. Nitrogen fixing bacteria (including associated and free-living bacteria) were 10^{3}–10^{-6} CFU g^{-1} $liter^{-1}$, similar to the microbial population found in the fertile soils of Red River delta. Microbial population at different soil depths was different in both density and diversity. Nitrogen fixing and P solubilizing bacteria were 10^{4}–10^{6} CFU g^{-1}.

Land Allocation

Until 1958, Thanh Ha was a French farm known as Xa Tanh and it was under coffee plantation. Between 1958 and 1960, Vietnam army managed it with no change in the cropping system. The Thanh Ha State Farm was established on 10 December 1960 under the administrative control of the erstwhile Farm Ministry, but army continued to manage the farm with coffee and orange plantation until 1975. Since 1975, the farm has been transferred to the National Fruit and Vegetable Company. Starting December 1995, the State Farm came under the administrative control of Hoa Binh province. The farm was divided into 7 villages and the ownership rights were given to the farmers. The allocation of household plots and annual cropland was done with most households receiving the land where their families had historically lived and worked.

Trends in Land Use and Livelihood Strategies

Government policy reforms over the past decade have attempted to re-establish the household as the basic unit of production and promote greater productivity. The Land Law of 1987, recently amended in 1993, and Decree 327 among other legislations, facilitated the allocation of agricultural and forest land to households on a long-term basis for productive activities. New credit facilities have been made available to enable farmers to invest in upgrading the land and diversifying production, while tax policy has been adjusted to reward greater productivity. The manner in which the farm households are responding to these new opportunities, redeploying their resources and reorienting their livelihood strategies may be instructive for the future development of this region.

Socioeconomic Conditions of the Benchmark Site

Demographic and social parameters of Thanh Ha State Farm and Village #7 are presented in Table 1. Fifty-three percent of the total land area (1522 ha) was suitable for agricultural purposes and only 28% was being cropped. However, 34% of the total area was under cultivation in Village #7. Recently, most of these lands were brought under arable cropping.

Table 1. General information on Thanh Ha State Farm and Village # 7.

	Thanh Ha State Farm		Village # 7	
Category	ha	(%)	ha	(%)
Total area	1522	100	163	100
Arable	803	53	56	34
Cultivated	424	28	-	-
Grasslands and fallow	379	25	-	-
Total reserve area	110	7	52	32
Forest	58	4	-	-
Small trees and shrubs	52	3	-	-
Roads and buildings	224	15	20	13
Other	358	25	35	21
Social parameters				
Number of families	868	-	62	-
Population	3352	100	350	100
Female	1732	52	182	52
Male	1624	48	168	48

Family Composition

The average family size was small with 58% of the population in the age group of 17 to 55 years. Because majority of the population was young and engaged in agricultural production, adoption of labor-intensive new production technologies and farming systems should not pose problem. The consensus among the survey participants was that their lives were better now than five years ago and anticipated that the trend of improvement in their socioeconomic condition would continue.

Cropping Patterns and Land Use

Northern Vietnam has four distinct seasons: spring (February–April), summer (May–July), autumn (August–October) and winter (November–January). Although ten different crops were grown in the watershed, major crops in terms of cropped area were maize (83%), sugarcane (8%), legumes (13%) and watermelon (6%). Groundnut was grown in the past but went out of cultivation because of severe problem of pod rot disease. Soybean was not cultivated in the watershed as no effort was made to introduce the same by the extension department. Cereal monocropping (maize-maize) was predominant and occupied 77% of the cultivated area (Figure 5). Cereal-legume cropping was only 2–3% of the total cultivated area. Watermelon-maize cropping system was also popular (11%).

Input Usage

The survey on input use in various crops revealed that high quantity of inorganic fertilizers was used (Table 2). Usage of organic manure (39–46 t ha^{-1}) was limited to watermelon and sugarcane. Insecticide usage was limited to sugarcane alone.

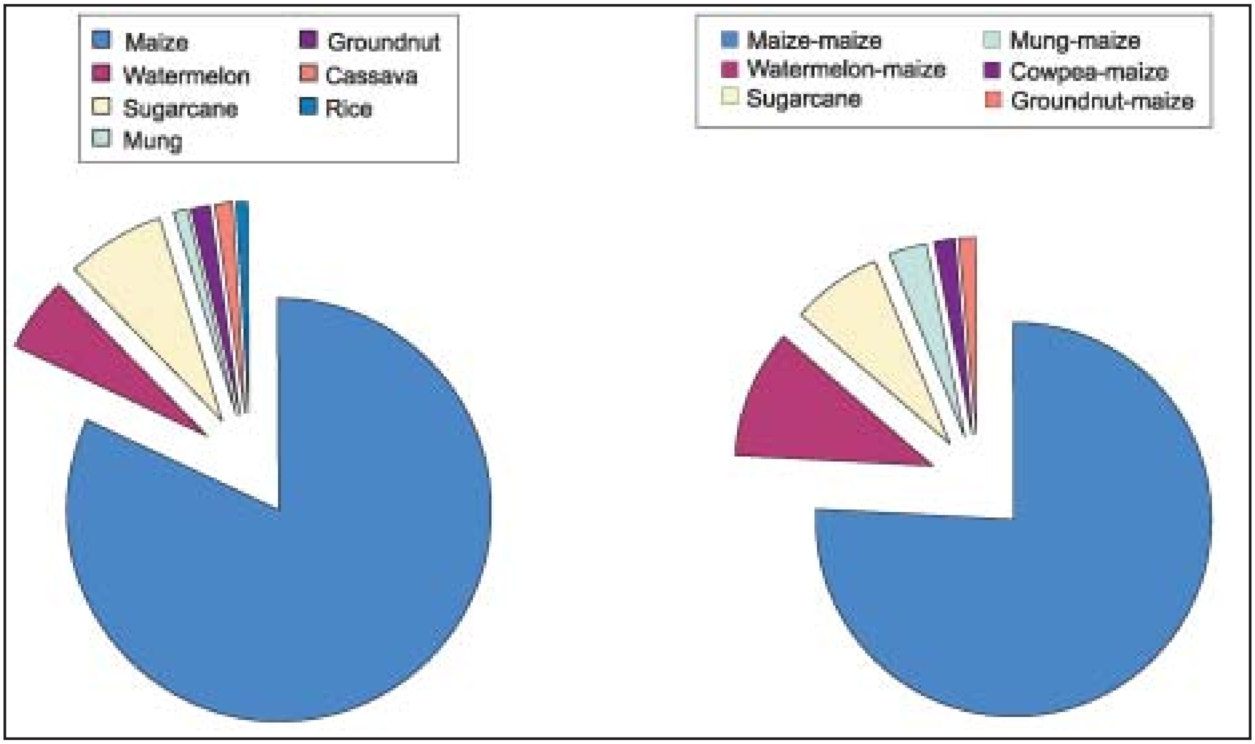


Figure 5. Crops and cropping systems in the study area.

Table 2. Input usage in various crops in Thanh Ha watershed.

Particulars	Maize	Watermelon	Sugarcane	Mung Bean	Cowpea	Rice
Seed (kg)	23	1.0		22	22.5	100
Urea (kg)	444	561	670	12	Nil	220
Super phosphate (kg)	525	579	554	500	500	500
Muriate of Potash (kg)	136	127	1467	Nil	Nil	85
Manure (t)	Nil	46	39	Nil	Nil	10
Labor (person days)	198	552	414	190	215	200

Seed price (Dong/kg); maize 181,000, watermelon 554,700, mung bean 11,180; cowpea 14,000 and rice 2500
1 US$ = 14,000 Dong

Crop yields

The average yields of all the crops were low to moderate (Table 3) with a wide range [maize 0.9–7 t ha^{-1}, watermelon 10–36 t ha^{-1} and mung 0.3–1.2 t ha^{-1}]. Discussions with the farmers revealed that production potential was high if appropriate crops and production technologies were used. Improved seed and cultural practices were being adopted in maize while production practices were at subsistence level in most other crops.

Economics of the crops and cropping systems

Benefit cost ratios for major crops and cropping systems were worked out. Cost (C) benefit (B) analysis of various crops (Table 4 and Figures 6a, 6b) indicated that watermelon and mung bean had the highest B:C ratio (1.78 and 1.94), while sugarcane cultivation had the lowest (1.06). Among the cropping systems, highest benefit was being realized in watermelon–maize (2.19) and mung bean–

Table 3. Yield and output of crops grown in Thanh Ha State Farm.

Crop	Yield ($t\ ha^{-1}$) Range	Yield ($t\ ha^{-1}$) Average	Price ($\$\ kg^{-1}$)	Output ($\$\ ha^{-1}$) Average
Maize	0.9–7.0	3.4	0.12	423.08
Watermelon	10.0–36.0	17.8	0.11	2011.90
Sugarcane	20.0–83.0	58.3	0.01	560.00
Mungbean	0.3–1.2	0.7	0.54	380.00
Cowpea	0.6–1.2	0.8	0.39	308.57
Rice	3.0–6.1	3.2	0.14	434.29

1 US$ = 14,000 Dong

Table 4. Economics of crops in village #7 of Thanh Ha State Farm, 1998.

Crop	Sown area (ha)	Input cost ($\$\ ha^{-1}$) Labor	Input cost Inputs	Input cost Total	Output ($\$\ ha^{-1}$)	Benefit $\$\ ha^{-1}$	Benefit To rice (%)	B:C Ratio
Maize	55	138.24	158.05	296.29	423.08	126.79	80	1.43
Watermelon	36	393.92	733.85	1127.77	2011.90	884.13	561	1.78
Sugarcane	5	295.99	904.88	1200.87	1274.29	73.42	47	1.06
Mungbean	1	135.79	59.89	195.68	380.00	184.32	117	1.94
Cowpea	> 1	153.27	64.82	218.09	307.14	89.05	56	1.41
Rice	< 1	142.86	133.75	276.61	434.29	157.68	100	1.57
Average	-	210.01	342.54	552.55	805.12	252.57	-	1.53

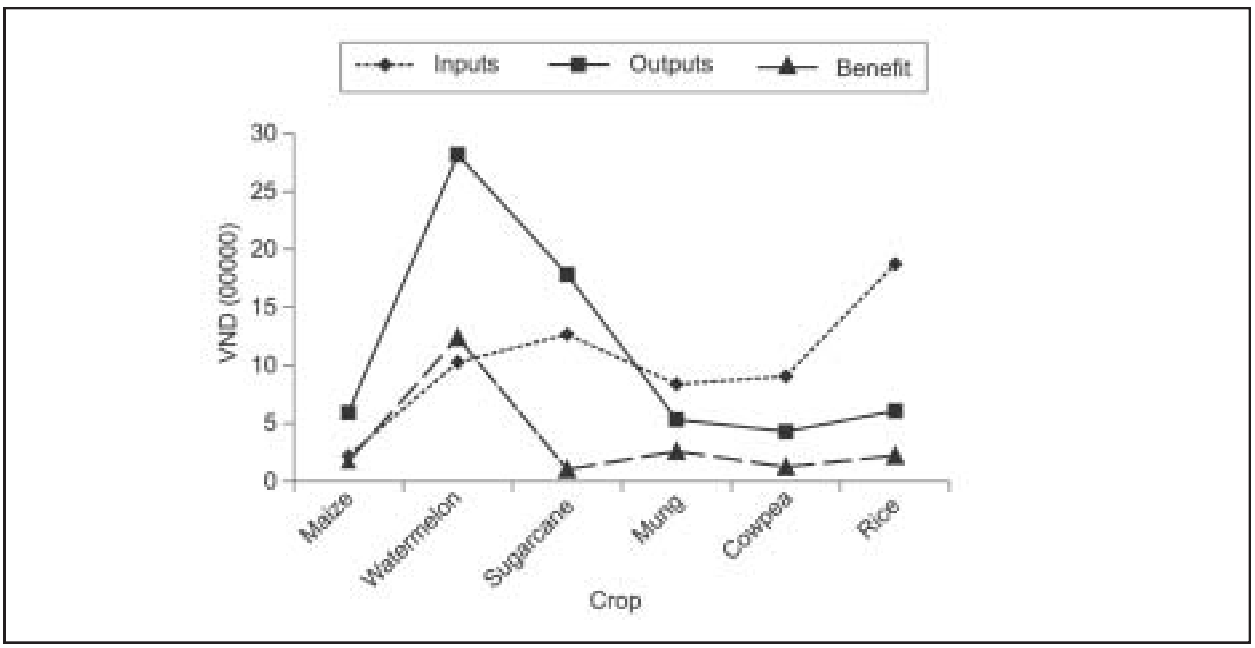


Figure 6a. Cost benefits of cultivating different crops.

maize (1.94) cropping systems. Cowpea–maize system (1.86) was the next best followed by maize–maize (1.42) cropping system (Table 5).

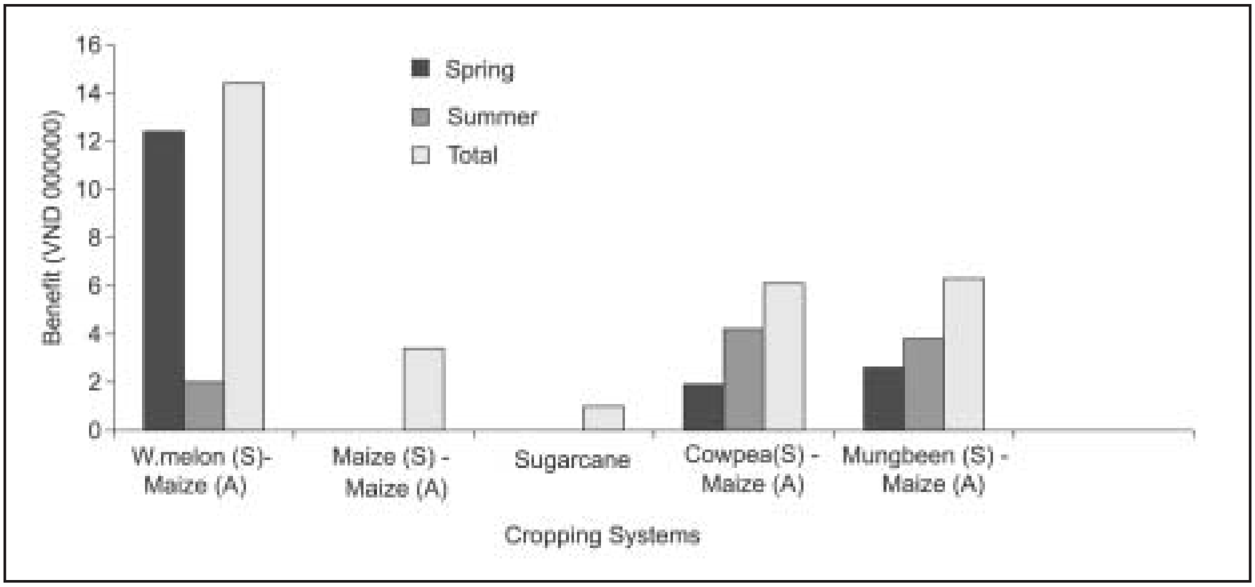


Figure 6b. Economics of different cropping systems.

Table 5. Economics of cropping patterns of village #7 of Thanh Ha State Farm.

Cropping Pattern	Sown area (ha)	Farms	Spring (000 $ ha^{-1}) Input	Output	Benefit	Summer - Autumn (000 $ ha^{-1}) Input	Output	Benefit	Total (000 $ ha^{-1}) Input	Output	Benefit	B: C ratio
W.M –M	7	12	1.13	2.02	0.89	0.29	0.44	0.15	1.14	2.5	1.36	2.19
M – M	50	47							0.6	0.85	0.25	1.42
S.cane	5	15							1.2	1.3	0.10	1.08
CP–M	< 1	2	0.2	0.34	0.14	0.31	0.61	0.3	0.51	0.95	0.44	1.86
MB – M	2	5	0.19	0.38	0.19	0.29	0.57	0.28	0.49	0.95	0.46	1.94

WM: watermelon, M: maize, CP: cowpea, MB: mung bean

Influence of Toposequence on Crop Productivity

The landscape watershed was divided into top, middle and lower part of the toposequence and the crop productivity differences were analyzed. Maize was grown on all the three toposequences while watermelon was grown only on middle and lower part of the toposequence. Higher benefit cost ratio was realized on the top of toposequence followed by middle and lower in maize, while lower part of the toposequence appeared to be ideal for watermelon over middle of the toposequence (Table 6).

Landholding and Profitability Relationships

Medium landholdings (1–2 ha) were predominant (58–62%). The relationship between size of landholding and profitability indicated that profitability reduced as the size of landholding increased in maize monocropping, while inverse relationship was noticed with watermelon–maize cropping system. Watermelon was a high input requiring commercial crop and profitability largely depended on adequate quantity and timely supply of inputs. The resource poor farmers could be facing the difficulty of meeting the crop demands in time resulting in low productivity and profitability. Secondly, marketing may not be economical in smallholdings because of high transport costs and non-availability of market facilities in the near vicinity. Nonetheless, maize input requirements were low and surprisingly small and medium landholdings invested more money over large landholdings. The

Table 6. Influence of toposequence on economics of crops.					
Crop	Location	Input ($ ha^{-1})	Output ($ ha^{-1})	Benefit ($ ha^{-1})	B:C Ratio
Maize	Top	364.71	668.07	303.36	1.83
	Middle	289.43	536.64	247.21	1.85
	Low	303.71	542.64	238.93	1.79
Watermelon	Top	-	-	-	-
	Middle	1137.14	1978.57	841.43	1.74
	Low	1080.79	2178.57	1097.78	2.02

yield differences in maize could be attributed to timely operations and appropriate care provided in small landholdings than in the medium and large landholdings (Table 7).

Landholding, Cultivated Area and Profitability Relationships

Landholding and profitability relationships in small, medium and large holdings indicated that small landholdings obtained higher profits from maize and sugarcane cropping, while large holdings obtained more profits with watermelon and rice cultivation (Table 8).

Table 7. Influence of landholding on cropping system profitability.

Cropping system	Land holding (ha)	Average holding (ha)	House holds (%)	Input ha^{-1} ($)	Output ha^{-1} ($)	Benefit ha^{-1} ($)	B:C ratio
Maize-maize	Small (<1)	0.7	21.3	632.57	1096.93	464.36	1.73
	Medium (1–2)	1.5	61.7	597.71	779.93	182.22	1.30
	Large (>2)	2.6	17.0	558.21	743.21	185.00	1.33
Watermelon-maize	Small (<1)	0.6	16.7	1374.57	1975.00	600.43	1.44
	Medium (1–2)	1.5	58.3	1406.50	2287.14	880.64	1.63
	Large (>2)	2.8	25.0	1472.07	3142.36	1670.29	2.13

Table 8. Influence of landholding on area sown and crop profitability.

Crops	Landholding (ha)	Average sown area (ha)	Input ha^{-1} ($)	Output ha^{-1} ($)	Benefit ha^{-1} ($)	B:C ratio
Maize	Small (<0.5)	0.4	332.00	575.71	243.71	1.73
	Medium (0.5–1.5)	0.9	296.29	442.00	145.71	1.49
	Large (>1.5)	2.0	280.00	296.86	16.86	1.06
Watermelon	Small (<0.2)	0.1	1397.36	1857.14	459.78	1.33
	Medium (0.2–0.4)	0.3	1066.64	1952.36	885.72	1.83
	Large (>0.4)	0.5	980.43	2285.71	1305.28	2.33
Sugarcane	Small (<0.2)	0.1	1393.21	2285.71	892.50	1.64
	Medium (0.2–0.4)	0.3	1106.43	1047.14	-59.29	0.95
	Large (>0.4)	0.5	1357.14	0.00	-1357.14	0.00
Rice*	Small (<0.3)	0.2	568.79	691.71	122.92	1.22
	Medium (0.3–0.5)	0.5	502.07	617.00	114.93	1.23
	Large (>0.5)	0.8	488.07	662.86	174.79	1.36

* Data from spring 2000 crop.

Household Capital and Income Relationships

Households were divided into poor, moderate and affluent based on the resources available (all fixed and movable assets except landholding) and influence of household capital on cropping system productivity and income generation was worked out (Table 9). Majority of the households (72–75%) were in poor category. Affluent farmers generated higher income over moderate and poor categories.

Table 9. Influence of household capital on income generation.

Cropping system	Capital groups	Household capital ($)	House holds (%)	Input ha^{-1} ($)	Output ha^{-1} ($)	Benefit ha^{-1} ($)	B:C ratio
Maize-maize	Poor (< 5 m)	118.57	72.3	602	805	203	1.34
	Moderate (5—10 m)	508.79	17	613.64	868.71	255.07	1.42
	Affluent (> 10)	1478.29	10.6	548.92	1042.85	493.93	1.90
Watermelon-maize	Poor (<5 m)	137.21	75	1415.85	2078.71	662.86	1.47
	Moderate (5 –10 m)	—	—	—	—	—	—
	Affluent (> 10 m)	1160.50	25	1422.85	3559.5	2136.65	2.50

Influence of Inputs on Productivity and Income Generation

The productivity of a given crop or cropping system depended on adequate inputs. The profitability fluctuated with both high and low input levels. An effort was made to find out appropriate level of input requirements in the major crops of Thanh Ha State Farm. For high benefit cost ratio, maize required an input of $313, while watermelon required $938. Sugarcane gave low profit at both low ($1000) and medium ($1000–1429) levels and caused losses at high ($1429) input level. Maize-maize cropping system needed an investment of $786 for good profits, while it was better to confine investment to $1107 in watermelon-maize cropping system as high levels of investment was deleterious (Table 10).

Constraints to Production

The survey has brought out the following important constraints faced by the farmers in the benchmark watershed.

Farmer perceived

- Lack of water for crop intensification (97.9%)
- Unavailability of credit and complicated loan procedures (91.8%)
- Fertilizers are expensive (83.7%)
- Lack of capital to purchase inputs (80%)
- Lack of knowledge on plant protection and improved production practices (79.6%)
- Monopoly of market forces (75.5%)
- Non-availability of market facilities (71.4%)
- Lack of extension services and demonstration of new technologies (71.4%)
- Non-availability of farmyard manure (67.3%)

Crop/ cropping system	Input level ha^{-1} ($)	Input ha^{-1} ($)	Output ha^{-1} ($)	Benefit ha^{-1} ($)	B:C ratio
Maize	Low (< 250)	226.57	327.50	100.93	1.45
	Medium (250–362.86)	294.57	413.21	118.64	1.40
	High (> 392.86)	420.50	647.14	226.64	1.54
Watermelon	Low (< 857.14)	804.21	1547.57	743.36	1.92
	Medium (857.14–1285.71)	1119.71	2440.40	1320.69	2.18
	High (> 1285.71)	1467.43	1619.07	151.64	1.10
Sugarcane	Low (< 1000)	971.00	1035.93	64.93	1.07
	Medium (1000–1428.57)	1207.21	1352.86	145.65	1.12
	High (> 1428.57)	1867.50	1714.29	-153.21	0.92
Rice*	Low (< 428.57)	427.71	576.00	148.29	1.35
	Medium (428.57–500)	460.07	621.43	161.36	1.35
	High (> 500)	549.93	682.43	132.50	1.24
Maize-maize	Low (< 500)	461.50	516.64	55.14	1.12
	Medium (500–785.71)	587.43	832.29	244.86	1.42
	High (> 785.71)	841.00	1294.29	453.29	1.54
Watermelon-maize	Low (< 1107.14)	1073.93	2018.36	944.43	1.88
	Medium (1107.14–1678.57)	1475.00	1321.43	-153.57	0.90
	High (> 1678.57)	1919.07	1871.93	-47.14	0.98

Table 10. Influence of inputs on income generation.

Researcher perceived

- Soil erosion
- Inappropriate soil, water and nutrient management practices
- Improper land use planning
- Natural resource base degradation

Constraints and Opportunities

We examined the constraints (in the farming systems and its environment) that limit the systems productivity and made an attempt to focus on opportunities that increase the system's productivity. A number of specific challenges were identified that needed to be addressed for development to be carried out successfully in the sloping ecoregions of the northern Vietnam. A distinction was made between the constraints that in principle can be addressed directly by the research team ('*addressable*') and those that cannot be addressed ('*non-addressable*'). A priority list of constraints and opportunities identified is provided hereunder.

Constraints

- *Physical constraints:* broken terrain, steep slopes and poor soils.
- *Environmental constraints:* deforestation, land degradation, moisture stress during critical stages of crop growth and low biological productivity.
- *Infrastructure constraints:* inadequate communication, transportation and production infrastructure and unskilled agricultural force.
- *Economic constraints:* subsistence orientation, inadequate development of market and trade.
- *Cultural constraints:* low levels of education and knowledge and persistence of traditional pattern of behavior.
- *Intellectual constraints:* inadequate scientific knowledge of the sloping land ecoregions and lack of suitable strategies to guide development and planning.

Opportunities

- The benchmark watershed has good potential for introduction of new crops and cropping systems because the current cropping systems are giving meager income and mining the soil fertility with associated erosion of natural resource base.
- Identification and/or introduction of appropriate technologies with focus on soil, water and nutrient management at micro-level in a watershed context will help optimize food production and arrest further erosion of natural resource base.
- Farmers are currently relying on high doses of inorganic fertilizers with little or no application of organic fertilizers. Good scope exists for introduction of appropriate integrated nutrient management practices.
- Most farmers are unaware of improved production technologies. There is a need to demonstrate new crops/cultivars, integrated pest and disease management technologies and improved crop production practices.
- Develop a paradigm tailored to the special conditions of the sloping land ecoregions.

Farmers themselves were strongly aware of some constraints, while the team members perceived other constraints. The decision on which constraints to tackle first may be influenced by this difference in perception. For example, the researchers considered soil erosion hazard as the number one problem, while farmers did not regard it as being quite serious. Erosion hazard may be seen as a 'strategic' problem, ie, one which is likely to increase in the future unless measures are taken immediately. In order to build up credibility, the team, however, decided to first address those constraints, which the farmers considered urgent, even if they were not most important from researchers' point of view.

From Constraints to Solutions

We used several ideas and techniques from Tripp and Woolley (1989) in the analysis of constraints and goal-oriented project planning:

- Analyzed the causes underlying the major constraints.
- Examined whether there is sufficient evidence for these causes, if not take up diagnostic research to find answers.
- Looked at whether a constraint or cause could be tackled directly by on-farm testing with available technology, if not develop the technology.
- Chose specific, well-defined technologies for on-farm testing.

The examples of groundnut and soil fertility are given in the Table 11.

Choosing the most appropriate technology always requires a good knowledge of both the target system and range of available technological options. Knowledge of the target system and the farming environment was obtained from the diagnostic survey and through collection of information. Knowledge about the technology was obtained by means of systematic search for information from experts, literature and existing databases. The following questions were also considered before planning the technological options.

1. Has the target system been clearly defined in terms of location, cropping system and the type of farmer?
2. Is the specific technology adapted to the ecological conditions of the target area?
3. Will the technology contribute effectively to the solution of the problem?

Table 11. Prioritization of constraints, likely causes and research activity by the on-farm team to address them, Thanh Ha State Farm, Vietnam.

		Technology testing		
Constraint	Cause	On-farm	On-station	Additional diagnostic studies
Failure of groundnut because of pod rot	• High disease pressure	• Introduction of high yielding, disease-resistant cultivars. • Introduce appropriate IPM technologies	• Screening of potential cultivars	• Quantify fungus build up and disease relationships • Identify hot spots and abandon fungus-infested fields.
Declining soil fertility and crop productivity	• Continuous maize mono-cropping • Shortening fallow • Soil erosion	• Integration of legumes. • Introduction of integrated land, water and nutrient management technologies	• Screening potential legumes • Seed multiplication	• Characterization of soil resource

4. Does the technology make other contributions to the farm as a whole?
5. Does it increase risks?
6. What does the technology require in terms of land, labor, cash or material investment from the farmer?
7. Does it require special extension efforts?
8. How does the technology fit into farmers' system, ie, where is the niche for integrating it? Does it interfere with other parts of the system, for instance, livestock?
9. Are there other social, cultural or policy issues affecting farmer adoption?

Farmer's Involvement in the Choice of Innovations

The research team, after carrying out the ex ante analysis of possible innovations, met the cooperating farmers and discussed the proposed innovations and solicited farmers' inputs. The average landholding in Vietnam is very small (1000 m^2 upland or 600 m^2 rice field) and the production losses if any because of improper practices advocated need to be compensated. The approach adopted therefore, is to encourage maximum participation of farmers in planning and execution of all our activities. All the watershed interventions, viz, introduction of new crops and cropping systems, soil and water conservation, INM, IPM etc, are thoroughly discussed and decided by the farmers. Researchers and extension workers aid in decision-making process and facilitate agreed activities by providing technical support.

Micro-watershed is used as a demonstration block for appreciating the benefits in terms of reduced runoff and soil loss through scientific measurements. Farmers in rest of the watershed evaluate improved soil, water and nutrient options and cropping systems along with IPM and IDM for efficient use of natural resources and sustainable productivity gains. Studies on nutrient budgeting and micronutrients requirements for different systems are underway with close cooperation and involvement of farmers.

References

Tripp R and Wolley J. 1989. The planning stage of on-farm research: identifying factors for experimentation. Mexico City, Mexico: International Centre for Maize and Wheat Improvement; and Cali, Colombia: International Centre for Tropical Agriculture. 91 pp.

Appendixes

Appendix 1

Brief information about the three watersheds in Shankarpally Mandal, Ranga Reddy District, Andhra Pradesh.

Village	Watershed area (ha)	Major soil type	Crops	Remarks
Kothapally	415	Black Soil	Sorghum, cotton, maize, pigeonpea, chickpea, paddy, turmeric, vegetables and flowers.	More dry land area, low crop yields and no water storage structure exists – potential area for adoption of Vertisol Watershed Technology.
Ravulapally	535	Black Soil	Turmeric, sugarcane, cotton, paddy, maize, pigeonpea, chickpea, vegetables and flowers.	Most deep black-soil areas are well developed through lift irrigation, good crop yields.
Fathepur	658	Black Soil	Sorghum, cotton, maize,pigeonpea, paddy, turmeric, chickpea, vegetables and flowers.	Shallow soils are predominant; land shown was not under cultivation for 2 years. Black soil area is irrigated and farmers are progressive.

Appendix 2

International Crops Research Institute for the Semi-Arid Tropics

Techno-economic survey for production practices and Constraint analysis in watershed areas

Name of Watershed ______________________

I. General Information

1. State : ______________________
2. District : ______________________
3. Taluka : ______________________
4. Village : ______________________
5. Household No. : ______________________
6. Name of Household : ______________________
7. Sex : Male / Female
8. Educational Qualification : ______________________
9. Main source of income : ______________________
10. Secondary source of income : ______________________
11. Farmer was earlier watershed program participants : Yes/No
12. Bank Loan : Availed Rs. ____________ year
    Outstanding Rs. ____________ year
13. Contact with extension agents : Regular/Monthly/Yearly/ Occasionally/Never
14. Distance to market : ____________ (km)
15. Name of the Investigator : ______________________
16. Date of Interview : ______________________

II. Resource Availability

1. Landholding Information (in acres)

Class	Owned Cultivated	Leased in	Share cropped in	Leased out	Share cropped out	Fallow land	
						Current	Permanent
Wetland							
Dryland							
Total land							

Total operated area (acres): in *kharif* ____________ in *rabi* ____________
in summer ____________

Rent (or share) in case of leased-in/leased-out (or share-in/share-out)

2. Characteristics of Soil

Soil texture	:	Sandy/loam/clayey/other (specify)
Soil type	:	Alluvial/Red/Black /Other (specify)
Topography	:	Upland /Mid land/Low land
Depth of soil (m)	:	____________________

3. Source of irrigation : Canal/Dugwell/Tubewell/Tank/River/Others

4. Family members and other resources engaged in agriculture

	Always	Peak periods
Male	____________________	____________________
Female	____________________	____________________
Child	____________________	____________________
Regular Farm Servant	____________________	____________________
Bullocks	____________________	____________________
Tractors	____________________	____________________

5. Household composition

Name	Sex	Age	Year schooling	Labor force participation (Check)			
				Daily farm wages	Off farm work	Seasonal migrant	Work on own farm or business

6. Farm equipment

Item	Number	Value
Iron plough		
Wooden plough		
Blade harrow		
Jumbo		
Gorru		
Electric Motor		
Oil Engine		
Mhote		
Persian wheel		
Bullock cart		
Crow bar		
Spade		
Khurpi		
Sickle		
Axe		
Bicycle		
Others		
(Specify……………………)		
(Specify……………………)		
(Specify……………………)		
(Specify……………………)		

7. Livestock

Species and type	Number	Value
Bullocks (improved breed)		
Bullocks (local)		
Milch cows (crossbreed)		
Youngstock (cattle)		
He buffaloes		
She buffaloes		
Youngstock (buffaloes)		
Goats		
Sheep		
Pigs		
Poultry		
Others(specify……………………)		
(specify……………………)		

III. Cropping Pattern:

Year: ________________

Plot Sl. No./ Name	Sub-Plot	Ownership status[1]	Crop/ Intercrop	Proportion[2]	Cropped Area	Season[3]	Land quality	Irrigated Area	Variety	Location of the plot[4]

1. Owned / leased-in / share cropped-in / leased-out / share cropped-out
2. Always main crop is first
3. K = *kharif*; R = *rabi*; S = Summer; P = Perennial
4. Specify; upland, low land and normal

Intercropping systems

Do you practise intercropping: Yes/No

If yes, what are the preferred intercropping systems.

Intercrop (i) ________ (ii) ________ (iii) ________

Area (i) ________ (ii) ________ (iii) ________

Irrigated Area (i) ________ (ii) ________ (iii) ________

Reasons for taking intercrop

1.
2.
3.

Sequential cropping

Do you go for sequential cropping: Yes/No

If yes,

Sl. No.	Crop Sequential		Area	Irrigated area
	kharif	*rabi*		

Reason for going to sequential crop:

____

____

Which system has the potential for double cropping

Name of the crop: ________________________________

Reasons: ________________________________

____

____

Sole crop

Do you plant only one crop a year in one or more plots: Yes/No

If yes:

Sl. No.	Crop	Area	Irrigated area

IV. Crop disposition: Year: ____________

Production/disposition and market price	Name of crop and season					
	Crop:					
	Season:					
Total production						
Grain or main product in ……. Unit						
Fodder or by product in …….. unit						
Disposition						
Marketed						
In-kind payments to labor						
Loan repayment						
Still held in storage						
Consumed						
Other						
Sale price, if marketed						

V. Fertilizer and pesticide adoption:

(a)	Have you ever used inorganic fertilizer?
(b)	If yes, in what year did you first start to use inorganic fertilizer?
(c)	Do you apply fertilizer every year?
(d)	Do you apply FYM every year? If not, how often?
(e)	Have you ever used pesticide?
(f)	If yes, in what year did you first apply?
(g)	Do you own sprayer?
(h)	If not, are sprayers readily available?
(i)	Is fertilizer readily available throughout the year?
(j)	Are pesticides readily available throughout the year?

VI. Adoption of soil conservation practices

Practice	Adoption			Reasons for non/partial adoption					
	Not adopted	Adoption on at least one field	Adoption on all fields	Lack of knowledge	Not technically suitable to their specific location	Too costly	Not convenient	Neighboring farmers do not cooperate	Other risks
Keyline cultivation									
Levelling and smoothing									
Waterways									
Dugout ponds for water reuse									
Water waste weirs									
Deep ploughing									
Deep furrows									
Keyline cultivation									
Dead furrow									

VII. Credit and financial liabilities

Source of credit	Amount		Rate of interest	Security offered	Purpose of loan
	Borrowed	Outstanding			
Banks (specify)					
1.					
2.					
3.					
Government agencies					
1.					
2.					
3.					
Cooperative societies					
1.					
2.					
Money lenders					
Farmers					
Friends and relatives					

VIII. Input-output information

Crop: Variety: Plot no: Area: Row arrangement:
Sub-plot: or proportion

Operations		Labor use[1]		Input/Output			
		Unit	Qty	Wages	Qty	Unit price	Remarks
1A. Land preparaftion (Ploughing-primary and secondary tillage	M	D					
	F	D					
	B	D					
	T	HR					
1B. Seedbed preparation (BBF/NBF/FLAT)	M	D					
	F	D					
	B	D					
	T	HR					
2. FYM/Compost/Sheep penning/ Tank silt application	M	D					
	F	D					
	B	D					
	T	HR					
FYM/Compost		QT					
Animal penning		NO					
Date of sowing							
3. Planting/Sowing	M	D					
	F	D					
	B	D					
4A. Seed: Crop 1		KG					
Crop 2		KG					
Crop 3		KG					
4B. Seed treatment	M	D					
	F	D					
....		GM					
....		GM					
5A. Fertilizer application	M	D					
	F	D					
……..		KG					
……..		KG					
……..		KG					
……..		KG					
……..		KG					
5B. Micronutrient application	M	D					
	F	D					
……..		KG					
……..		KG					
……...		KG					

Operations		Labor use[1]		Input/Output			
		Unit	Qty	Wages	Qty	Unit price	Remarks
6. Interculture	M	D					
	F	D					
	B	D					
7. Weeding/weedicide application	M	D					
	F	D					
	SP	HR					
……..		LT					
……..		LT					
8. Plant protection/spraying /dusting/shaking plants/ hand picking pest							
	M	D					
	F	D					
	B	D					
	SP	HR					
	DU	HR					
……..							
……..							
……..							
……..							
9. Irrigation	M	D					
	F	D					
	HR						
Source of Irrigation							
10. Watching (Birds, Pigs, etc.)	M	D					
	F	D					
11. Harvesting[2]: Crop 1	M	D					
	F	D					
Date of harvesting Crop 2	M	D					
	F	D					
Crop 3	M	D					
	F	D					
12. Threshing: Crop 1	M	D					
	F	D					
	B	D					
	TH	HR					
Crop 2	M	D					
	F	D					
	B	D					
	TH	HR					
Crop 3	M	D					
	F	D					
	B	D					
	TH	HR					

Operations		Labor use[1]		Input/Output			
		Unit	Qty	Wages	Qty	Unit price	Remarks
13. Marketing (including transport, storage and labor charges)	M	D					
	F	D					
	B	D					
14. Fixed Cost: Land rent	T	HR					
Cash		RS					
Kind		KG					
Land Tax:							
15. Grain yield: Crop 1		KG					
Crop 2		KG					
Crop 3		KG					
		KG					
		KG					
16. Fodder yield: Crop 1		QT					
Crop 2		QT					
Crop 3		QT					
		QT					
		QT					
17. Stalk: ……..		QT					
……..		QT					

1. Labor input includes total labor days of family and hired labor for each operation. Specify male and female labor as well as bullock labor separately wherever necessary.
2. Estimate the labor requirement if you had given to contractor for harvesting.
3. Specify clearly the units (eg. 5 kgs, FYM – 2 tons etc.).
   M = Male labor, F = Female labor, B = Bullock labor,
   T = Tractor/Truck, TH = Thresher, SP = Sprayer, DU = Duster.
   Note a: In irrigation operation use codes from code book.
   Note b: Cost of hiring tractors/bullocks includes cost of operator.
   Note c: Ask/calculate land rent for particular crop only.

IX. Sources of information

- State Agricultural Departments
- Research Institutions (Specify)
- NGOs (Specify)
- Private Agencies (Specify)
- Relatives/Friends
- Other farmers
- Through Magazines/News Papers
- Radio
- Private Seed Dealers

X. Constraints in production practices:

A. Pertaining to technology YES/NO

1. Seed and seed treatment
   a. Low germination
   b. Low purity
   c. Uneven germination because of uncontrolled depth
   d. Late sowing because of unavailability of seed in time
   e. Complete immunity not ensured by seed treatment
   f. Lack of local supply of improved seed
   g. Lack of knowledge about method of sowing
   h. Unavailability of suitable variety as recommended

2. Water management
   a. Lack of irrigation
   b. Undulated land
   c. Lack of knowledge about irrigation method and time
   d. Alternative irrigation is not possible
   e. Defective land shaping
   f. Water is not supplied when required
   g. Stagnation of water in the field because of inadequate drainage system
   h. Declining water table

3. Fertilizer and manurial management
   a. Judicious balancing with recommended phosphatic and potassic fertilizer is not necessary in our soil.
   b. High doses of fertilizers spoils the soils.
   c. Induction of more disease and pests through application of fertilizer
   d. Fertilizer application is more expensive
   e. Loss of fertilizer through leaching and runoff
   f. Due to poor soil conditions
   g. Lack of timely supply
   h. Non-availability of FYM
   i. Poor quality of FYM
   j. Lack of timely supply of FYM
   k. Lack of fertilizer supply
   l. FYM is not necessary
   m. FYM application

4. Weed control
   a. Chemical application not effective as hand weeding
   b. Difficulty in weeding in irrigated field
   c. Weedicide cause toxicity to crop
   d. Hand weeding time and labor consuming thus expensive
   e. High cost of weedicides
   f. Inadequate or nil knowledge of weedicide use

5. Disease and pest control
    a. Spraying is not effective
    b. Most of the diseases/pests are not controllable
    c. Lack of supply of plant protection material
    d. Capital insufficient
    e. Lack of knowledge about plant protection
    f. Lack of local supply
    g. Chemicals are more toxic to the animal and human
    h. No problem of disease and pest in the field

6. Harvesting and threshing
    a. Difficulty in harvesting because of stagnation of water in the fields
    b. Appropriate time cannot be judged
    c. Lack of fruit picker

B. Pertaining to labor management

1. Shortage of labor at the time of ____________________
2. High wages of labor at the time of ____________________
3. High labor mobilization at the time of ____________________
4. Skilled/labor shortage for the purpose of ____________________

C. Pertaining to Institutional infrastructure

1. Credit
    a. Not available from one agency and in time
    b. Rate of interest is not only high but varies from agency to agency
    c. Complicated loaning procedure
    d. Recovery procedure is stringent
    e. The various fees, charges, as well as the cost involved in running of credit agencies several times are very high

2. Marketing
    a. Monopoly and forced marketing in grain market/vegetable market
    b. Late and inadequate return in the market
    c. Market located at a distance place
    d. More transportation charges
    e. Unauthorized charge

3. Extension
    a. Farmer training conducted at distance places
    b. Improved production techniques are not demonstrated in the field
    c. Intensive contact of subject matter specialist from University and Agricultural Department with farmers in very low
    d. Key information and village youth are not feed with important technical information

Techno-economic survey for production practices and constraint analysis in watershed areas

Name of Watershed ______________________

Guide questionnaire for Rapid Rural Appraisal

Village information

Name of the village	:	______________________
Name of the tehsil	:	______________________
Name of the District	:	______________________
Total population of village	:	______________________
Total cultivating households	:	______________________
Total labor households	:	______________________
Total cultivated area in village	:	______________________
Total fallow land in the village	:	______________________
Total irrigated area in the village	:	______________________
Source of irrigation	:	______________________
Average landholding	:	______________________
Soil types in the village	:	______________________
Major cropping patterns	:	______________________
		______________________
		______________________
Government schemes operating	:	______________________
No. of Sprayers in village	:	______________________
Distance of Fertilizer and Pesticide shops from village	:	______________________

About ICRISAT

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political, international organization for science-based agricultural development. ICRISAT conducts research on sorghum, pearl millet, chickpea, pigeonpea and groundnut – crops that support the livelihoods of the poorest of the poor in the semi-arid tropics encompassing 48 countries. ICRISAT also shares information and knowledge through capacity building, publications and information and communication technologies (ICTs). Established in 1972, it is one of 15 Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

Contact information

ICRISAT-Patancheru
(Headquarters)
Patancheru 502 324
Andhra Pradesh, India
Tel +91 40 30713071
Fax +91 40 30713074
icrisat@cgiar.org

Liaison Office
CG Centers Block
NASC Complex
Dev Prakash Shastri Marg
New Delhi 110 012, India
Tel +91 11 25849552/25842553/25841294
Fax +91 11 25841294

ICRISAT-Nairobi
(Regional hub ESA)
PO Box 39063, Nairobi, Kenya
Tel +254 20 7224550
Fax +254 20 7224001
icrisat-nairobi@cgiar.org

ICRISAT-Niamey
(Regional hub WCA)
BP 12404
Niamey, Niger (Via Paris)
Tel +227 722529, 722725
Fax +227 734329
icrisatsc@cgiar.org

ICRISAT-Bamako
BP 320
Bamako, Mali
Tel +223 2223375
Fax +223 2228683
icrisat-w-mali@cgiar.org

ICRISAT-Bulawayo
Matopos Research Station
PO Box 776,
Bulawayo, Zimbabwe
Tel +263 83 8311 to 15
Fax +263 83 8253/8307
icrisatzw@cgiar.org

ICRISAT-Lilongwe
Chitedze Agricultural Research Station
PO Box 1096
Lilongwe, Malawi
Tel +265 1 707297/071/067/057
Fax +265 1 707298
icrisat-malawi@cgiar.org

ICRISAT-Maputo
c/o INIA, Av. das FPLM No 2698
Caixa Postal 1906
Maputo, Mozambique
Tel +258 1 461657
Fax +258 1 461581
icrisatmoz@panintra.com

Visit us at **www.icrisat.org**

378-2004