Chapter III

Research methods

The preceding chapter succinctly presented the complexity of the issue and need for integrating different tools and approaches to study the problem of natural resource management. This chapter presents the context of the issue, conceptual framework used in the study and analytical tools. There is an elaborate description of the role-playing game and MAS, which will form the two major tools used in this research.

3.1 Conceptual framework

The study followed the conceptual framework given in Figure 3. It comprises of three distinct phases that proceeded in an iterative manner. Step 1 constitutes general diagnosis of the study area to conceptualize the issue and the context. Characterization of farming systems and users categorizations was done based on historical profile, strategy, options, constraint and potential.

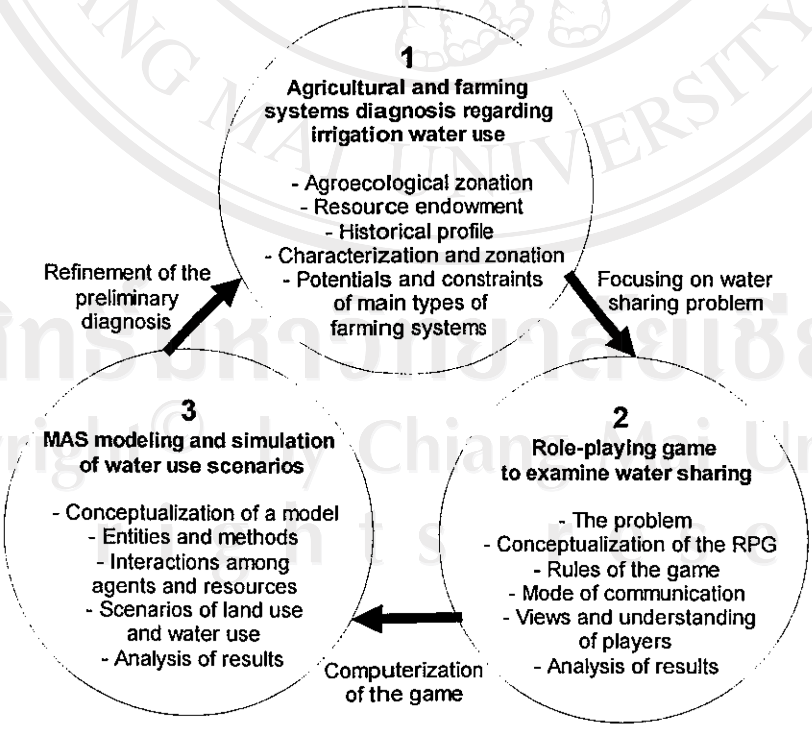


Figure 3. Schematic representation of conceptual procedure used in this study.

Subsequent step focused on role-playing game involving stakeholders in the process of collective learning by taking part in role-playing sessions. Step 2 thus helped in generating unique behaviors and actions through which greater understanding was acquired on water sharing systems in the community. The third step incorporated findings and understandings from the two earlier steps in development of agent-based models to generate scenarios of social network and exchange protocols. These scenarios helped in identifying different resource sharing mechanisms.

3.2 Setting

Common-pool resources (CPRs) play an important role in livelihoods of Bhutanese. Local demand for resources like timber, firewood, water, and non-timber forest products (NTFPs) resulted in the establishment of locally defined rules to regulate access to and use of the resources. As mentioned earlier, these local rules were derived from long-standing customs, religious traditions, and policies. Among the natural resources: wood resources, NTFPs, communal pasture, water, and communal agricultural resources are considered as critical resources (Ministry of Agriculture, 2002b). The management and use of this resource depend on the way people exercise their user-rights. Limited state capacity to effectively monitor and manage natural resources, combined with the loss of local management regimes has created an open access situation for many resources. In the process, there are signs of resource degradations and most importantly conflicts among the users are increasing. A few distinct types of degradation are:

- High demand of timbers, firewood and fodder in densely populated areas has resulted in barren forest.
- Overgrazing has affected natural regeneration of forest
- Commercialization of NTFPs such as lemongrass, cordyceps, chirata, matsutake mushroom has lead to over harvesting of the resources.
- Expansion of irrigation facilities resulted in increased option for cultivation and indiscriminate use of water leads to soil erosion. Inequitable irrigation sharing systems has led to social conflict.

Among the farming communities, access to irrigation water has always been a constraint to agricultural production. This limitation is mainly because irrigation water comes from secondary and tertiary tributaries, local streams and springs (Bhutan Water Partnership 2003). Information on water management system including water distribution and traditional rights is limited. It is important to establish adequate information and experiences on water management to help in policy formulation.

This study was conducted in a rural setting of west central Bhutan, where two communities have been in conflict over sharing irrigation water for many years. They divert water from Limtichu river into Dompola canal and share water. In Bhutan, most irrigation schemes are governed by traditional rules that were framed when demands were low and resource was in abundance. These traditional water rights are associated to the feudal past, where the original taxpayer (locally known as *Thruelpa*) has full rights over water resource. As water rights are attached to wetland and are inheritable, in the course of time other categories of irrigators (*Cheep and Chatro*) have evolved through inheritance. With the increase in population and fragmentation of land, numbers of certain categories of users has increased. At the same time resource supply declined. There are group of farmers (*Lhangchu*) who do not have water share and depend on other farmers. The detail share of water is explained in Chapter 3. In contrast, the rules on water use and sharing has not changed, which resulted in inequitable sharing of water. There are cases where upstream and downstream communities are in conflict because of disagreement in local water sharing systems. However, a greatest obstacle to mediation has been the resistance for change by those who are favored by the rules. This resistance has resulted in legal institutions upholding the principles of status quo, whenever these conflicts are reported to the district courts.

This study aims to understand the process of sharing water, its effects on resources and finally establish a communication mechanism between two communities to collectively learn and develop strategy.

3.3 Study Site

The Renewable Natural Resources Research Center in Bajo conducted preliminary diagnostic studies in Lingmuteychu watershed in 1997 as part of the community-based natural resource management research (Renewable Natural Resources Research Center, 1998). This study identified numerous constraints to low crop production in the watershed, of which lack of irrigation water during transplanting was reported as a major problem. Considering the problems and existing field experiences, the site was selected for this research.

Lingmuteychu is a small watershed located at 27°33′ N and 89°55′ E on the east bank of the Punatshang Chu river in west-central Bhutan, occupying an area of 34 km^2. It is drained by the 11 km long Limti Chu stream that originates as a spring from a rock face at an altitude of 2,400 m north of Limbukha village (Figure 4). It is a rainfed stream since the ranges that confine the watershed are below the snow line. The stream serves five irrigation systems supporting 11 irrigation channels that irrigate about 180 ha of terraced wetland belonging to 162 households of six villages (Renewable Natural Resources Research Center, 1998). These six villages share irrigation water within a broadly respected customary regime. The two villages of Limbukha and Dompola situated approximately 3 km apart in the upstream of Lingmuteychu watershed are in persistent conflict in sharing irrigation water.

The base flow during the dry months of April and May fluctuates at about 40 to 50 Ls^{-1}. The flow produced by a widespread rain in the watershed can be more than 500 Ls^{-1}. The rainfall-runoff response is quick and the stream returns to its base flow within a couple of days after the rainfall. The fluctuating nature of the stream mainly results from steep gradient of the watershed. The watershed receives an average annual rainfall of 700 mm (Renewable Natural Resources Research Center, 1998).

Regulations in terms of water diversion by different irrigation canals from the Limti Chu are based on two broad principles. The rule "first come, first served" applies, which means that existing schemes have an established water right and can prevent newcomers from using it.

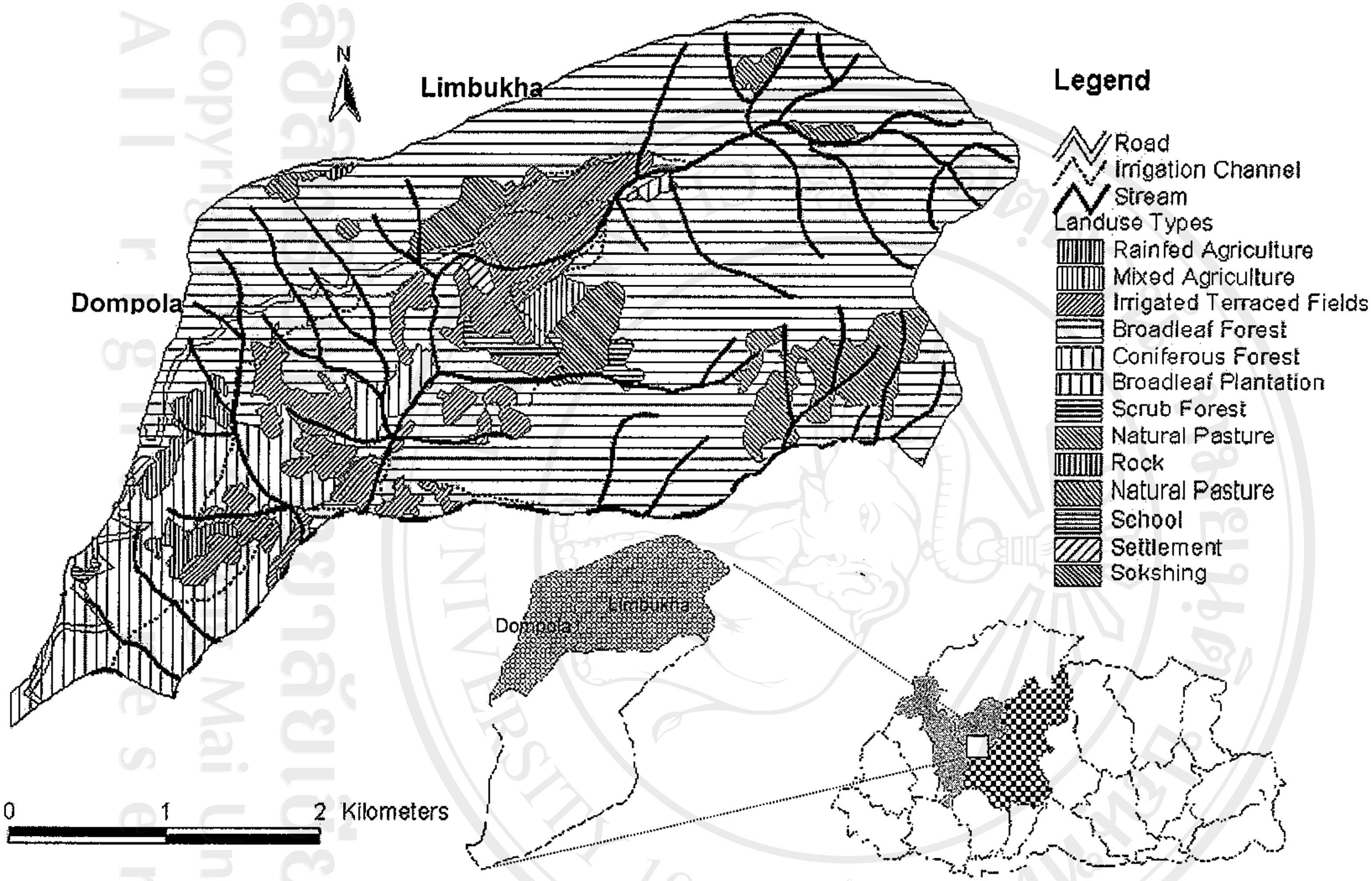


Figure 4. Map of the study area in Lingmuteychu watershed, Punakha District, West-central Bhutan.

For instance, Nabche (one of the villages within the watershed) is a resettled community and it does not have access to water, which prevents them from constructing an irrigation canal. The second rule can be interpreted as "more water for upstream communities." Conflicts arise particularly from these two rules. Under such water-use regime, the community in the uppermost catchment (Limbukha), close to the intake point, has absolute control over the headwater.

Ironically, Dompola, a second village in the upper catchment located approximately 3 km downstream from the intake point, does not have direct access to the stream. Dompola has to share water with Limbukha and the water release date and volume of water diverted from the stream are strictly followed. As per the traditional arrangement, Dompola gets half of the stream flow only from the tenth day of the fifth Bhutanese month every year. However, even after this date, Limbukha farmers still use water from Dompola's share to irrigate their land. As such, Dompola farmers struggle to get their paddy field transplanted. This indiscriminate use of water in the upper catchment results in conflict between two villages.

Within a village, water is shared on the basis of a rotation system locally known as "*chukor.*" The rotation interval among different communities in the watershed varies from 3 to 13 days. In Limbukha and Dompola, water is shared on the basis of four categories: "Thruelpa," "Cheep," "Chatro," and "Lhangchu." These categories correspond to the following modes of access to irrigation water:

- a thruelpa is entitled to half the flow in the canal (½ of canal flow)
- a cheep is entitled to half of thruelpa (¼ of canal flow)
- a chatro is entitled to half of cheep ($^{1}/_{8}$ of canal flow), and
- a lhangchu has no entitlement and has to beg for water

As shown above, the existing water rights are not equitable. As the water resource becomes scarce, the current system has deficiencies. With differences in water rights, conflict can emerge within and between communities. It has also been shown that farmers use excessive amount of water (Ministry of Agriculture, 2002b).

This is aggravated by the introduction of multiple-cropping practices in upper villages, which have strong effects on water supply and rice productivity in the lower community (Renewable Natural Resources Research Center, 1997).

3.4 Sampling technique

The sample households were selected by using multistage sampling technique. From the 7 villages in the Lingmuteychu watershed, Limbukha and Dompola having an acute and persistent conflict on water sharing were selected. Farmers of these two villages were classified based on their water sharing category and 6 farmers from each of the two villages were randomly selected to take part in the first session of role-playing game held in May 2003 (Table 7). These 12 farmers represented four water sharing categories (as explained in section 3.2).

Table 7. Category and number of players from Limbukha and Dompola for RPG

Category	Limbukha	Dompola
Thruelpa	2	1
Cheep	2	3
Chatro	1	2
Lhangchu	1	0
Total	6	6

The same players were requested to participate in the second session of RPG organized in December 2003 in Dompola. As majority of the players during first session of RPG suggested that Block development committee members and officials from District Administration be included as observers in such exercises, all Block development committee members and District Agriculture Officer participated as observers in the second session of RPG held in December 2003.

3.5 Data collection

To fill the information gap for the study, primary and secondary data were collected. A structured questionnaire was developed based on a preliminary analysis of the secondary data and the basic information needed for designing a role-playing game. Secondary data was extracted from various published and unpublished reports, journals, literatures, proceedings, personal communications, key informants and observations. Analysis of secondary data (Renewable Natural Resources Research Center, 1997; Duba and Swinkles, 2001) helped to focus this research. Institutions like Research Center in Bajo, District and Block Agriculture Office and Planning and Policy Division (PPD) of the Ministry of Agriculture provided both formal and informal information.

Primary data were collected using formal and informal methods. The basic purpose of the primary data collection was to make systematic diagnosis of the watershed and farming systems aspects related to the problem under study and to subsequently help in designing of the RPG. Initially informal visits to the site and discussions were held with the administrators, researchers, extension staff, community leaders, and some farmers. These discussions further helped to better understanding the problem and conceptualize the study.

A formal household survey was conducted using a structured questionnaire. The questionnaire was pre-tested in Limbukha followed by a survey of 40 households from the two villages. The household survey was targeted to collect data in three major areas: general socio-economic information, social organization, and irrigation water management. The role-playing game also generated information on management strategies both during the game and from the individual interview of the 12 players after the game.

3.6 Data analysis

Watershed and farming systems diagnosis was done using the agrarian system diagnostic analysis and farming system typology methods (Trébuil, 1992, Trébuil, 1993, Trébuil et al. 1997, Capillon et al., 1993). The agrarian system diagnostic analysis is made of three main and complementary methodological tools:

- agroecological zonation,
- historical profile of the agrarian system, and
- analysis of farmer differentiation/typology.

They aim at identifying factors which steer the way farmers choose economic activities and corresponding management options. They also aim at identifying the processes through which such strategies influence the transformation of the farmer typology. The farmer typology tool follows three basic steps:

Step 1: Characterization of the general functioning of agricultural production systems (APS) to display strategies, components of the system and factors influencing the strategy.

Step 2: Grouping of similar APS in main types.

Step 3: Construction of farmer typology.

For general analysis descriptive statistics were used for comparisons of outputs. Throughout the analysis, simple graphical outputs were used for discussions with farmers. Gross margin analysis was used in the RPG to calculate farm income during the game.

While individual performances of player in RPG could be efficiently monitored by land use changes, water use and income after each time step, the overall performance of the collective system cannot be shown clearly from the summated income. Therefore, as a synchronized output from the RPG, performance of irrigated agricultural system was used as an indicator to show player the impact of their collective actions on the performance of the irrigation system. Three indicators, adapted from Molden et al. (1998) were used to compare the performance of the irrigation system in the two villages. The analysis used gross margin and cropped area generated by the RPG simulation. The three indicators are as follows:

$$\text{Output per cropped area } (US\$\ ha^{-1}) = \frac{Gross\ margin}{Irrigated\ cropped\ area} \quad 1$$

$$\text{Output per unit command } (US\$\ ha^{-1}) = \frac{Gross\ margin}{Command\ area} \quad 2$$

$$\text{Output per unit irrigation supply } (US\$\ m^{-3}) = \frac{Gross\ margin}{Diverted\ irrigation\ supply} \quad 3$$

3.7 Role-playing game

3.7.1 Conception of the RPG

The RPG method was conceived as a potential tool to initiate and facilitate dialogue between the two villages and for the research-extension team to enhance their understanding of the problem. The conflict in these two villages relate to sharing of irrigation water, time of release and effect of changing cropping pattern, which further relates to the way resource is used within and between communities. In conceptualizing the game, the following features (Figure 5) were included:

- Players: Irrigators - water sharing category
- Roles: Play the game according to the assigned task
- Rules of the game: Set of broadly pre-defined steps of the game
- Game sets: Playing Board
- Turns (Round of play): 1 Year - (January-December)
- Gaming session: 3 days per session (May and December 2003)

Each turn was divided into 2 steps: January to June and July-December. In first cycle of a time step, Limbukha farmers planted potato and rice, while Dompola farmers planted only rice, based on their resources. In the second cycle, Limbukha farmers harvested potato and planted rice in their remaining plots. Dompola farmers also planted rice in the remaining plots in second cycle. There were two chance factors: rainfall (normal and low) and market price (high and low) which influenced water availability and income. Rainfall was declared after drawing a card at the start of the game, whereas the market price was declared after each round of play (crop year).

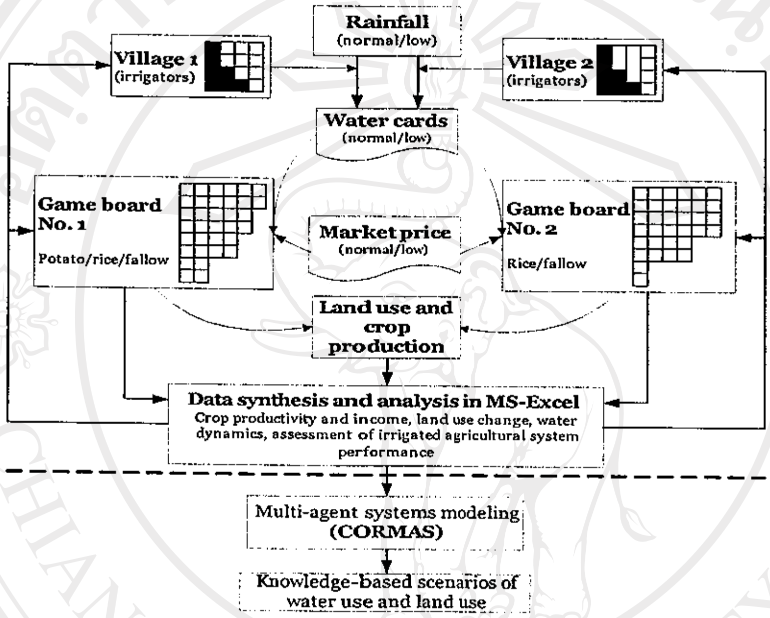


Figure 5. Diagrammatic representation of the Dompola role-playing game.

3.7.2 Game Board

Two game boards (one for Limbukha and the other for Dompola) were drawn on a 0.5 m * 1 m poster paper representing the farmers in columns and their plots in rows (Figure. 6). On the game board, columns represented six farmers. Rows represent plots, plain numbers ranging from 1 to 8 (depending on the category of the farmer). Each plot is equivalent to 0.1 ha of irrigated terraced field. Only one crop can be grown at a time. However, in the actual game, players proposed that Limbukha villagers could grow a crop of potato before any rice crop. The year and period of the game (e.g., 4/2: implying year 4 and cycle 2 of 2) were indicated in the lower right corner of the board. Players were given predefined numbers of rice fields: Thruelpa got 8 fields, Cheep got 6, Chatro got 4, and Lhangchu only 2. At the end of each crop year, the board with crop cards on was photographed and recorded to help in data analysis.

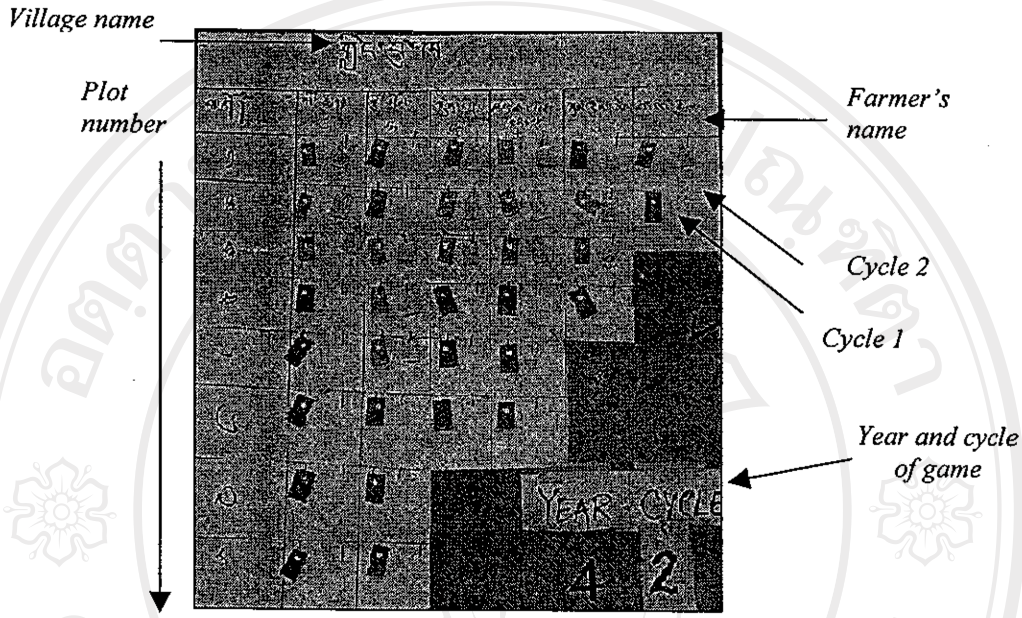


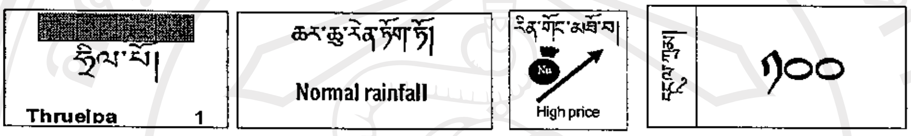
Figure 6. Game board of Limbukha village used in Dompola RPG, May 2003

3.7.4 Playing cards

Six types of cards were used as a medium in the game:

- *Name tag.* Each player was given a badge, which identified the bearer's social status and water-sharing category in public carries the name of the type of farmer and a four-squared box representing that person's share of irrigation water (Figure. 7a).
- *Cash.* Different denominations of local currency were used as cash to start farming and settle accounts after each time step. As the players introduced exchange of labor, cash was also used for labor transactions. One could borrow and lend. The card was used as an indicator of performance in terms of income. Each player received initial cash to start farming at the following rates: Thruelpa = Nu. 20,000 (US$1 = Nu. 47.10), Cheep = Nu. 15,000, Chatro = Nu. 10,000, and Lhangchu = Nu. 5,000.

- *Rainfall.* Two cards, normal (N) and low (L) rainfall for each cycle were used as chance cards to determine the volume of water available for irrigation and sharing. Depending on the rainfall pattern, the number of water received by each player were regulated to induce dynamism. Before each cropping cycle, the card was randomly drawn and declared.
- *Potato card.* Limbukha farmers received yellow cards representing potato fields. One card was equivalent to 0.1 ha of potato grown before rice. Each player could use a maximum of three cards, and could also skip a season without growing potato.



(a) (b) (c) (d)

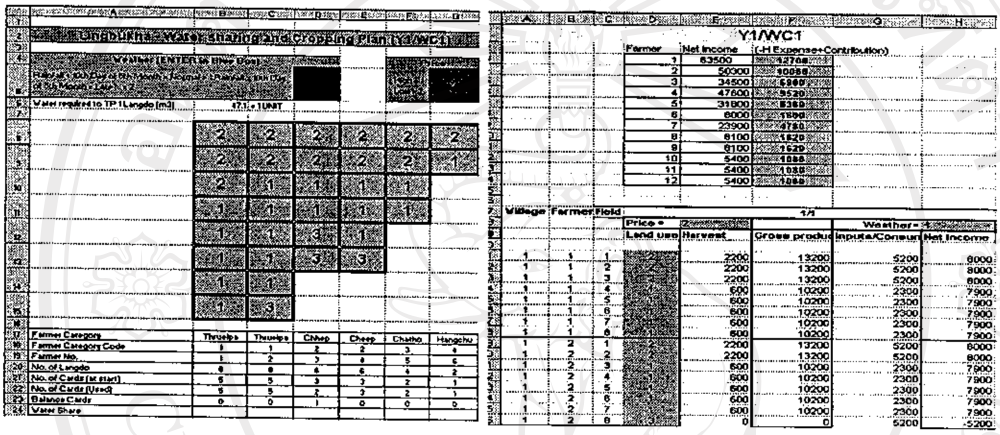
Figure 7. Cards used in the RPG in Limbukha

- *Water cards.* Pink and light blue cards were used to represent water. One pink card was used represent one unit of water, equivalent to the volume of water needed to transplant and irrigate 0.1 ha of rice. This means that farmers could place only one water card in one plot to indicate that that plot has been planted to rice. This card could be sold, exchanged, or used for transaction among villagers in a community or among farmers of the two communities. The game facilitator issued water cards in correspondence to the rainfall type. In the normal-rainfall season, Thruelpa received 5 water cards, Cheep 3 cards, Chatro 2 cards, and Lhangchu 1 card. During the low-rainfall pattern, the water provision was reduced by one unit, that is, 1 card less.
- *Market price.* Two cards representing a high and low price were used to indicate potato and rice prices. One of these cards was drawn randomly and declared after each crop cycle.

3.7.4 Spreadsheet

The data from RPG game boards were recorded in a spreadsheet (Microsoft Excel) for further analysis and synthesis. The data from the game board were transferred into a data-capturing spreadsheet (Figure. 8a) in codes (1 = rice, 2 =

potato, and 3 = fallow). The data were linked to a second spreadsheet (Figure. 8b) to calculate gross margin simultaneously. This spreadsheet acted as an interface between rounds of play (1 crop year), as it was used to calculate income from land-use decisions. Based on the results, each player was paid an income at the end of each year. Other data such as water dynamics and land-use changes were analyzed after all the gaming sessions concluded. This actually facilitated the gaming session by enabling rapid calculations and year wise comparisons if required.



a b

Figure 8. MS Excel Spreadsheet used in the Dompola RPG.

3.7.5 Pretest of the game

The game was pretested at the RNR Research Centre, Bajo, with researchers and trainees playing the role of farmers. Subsequent to the test, a few changes such as the number of plots and options for sharing water were incorporated into the game used with villagers during the following days. The test also helped to schedule the game in terms of time taken for each step. It also served the purpose of training selected facilitators and assistants before conducting RPG in the field.

3.7.6 Game sessions with villagers

In May 2003, the first gaming session was organized for 3 days in Dompola. The first day was assigned for RPG sessions. They started with a briefing about the game, the purpose, the role of the players, and the expected outputs. The game was played in three different modes of communication: village-based (intra-village), collective (inter-villages), and swapping roles. The first mode was played for 7 rounds of play (corresponding to 7 years). It represented the existing situation in which each village discussed water sharing independently at the village level and decided to grow different crops accordingly. Even the game boards were kept in distant places such that one village could not see the actions of the other village.

During the second mode of communication played for 5 rounds, farmers from both villages formed one group to discuss collectively water sharing between the two villages. The game boards were placed side-by-side to allow all players to see and discuss actions and situations on them. This was necessary to demonstrate that two villages can freely discuss and share water. During a shorter third scenario, roles were swapped between the two villages. This was anticipated to provide a better understanding of other village situations, identify any unique decisions, and bring about new understanding from swapping of the roles.

The second day was devoted to analysis of the RPG outputs and discussion among facilitators. On the third day, based on the preliminary analysis and observations, individual interviews with each player were conducted to collect views on the game and evaluate it. Following individual interviews, a plenary session was organized to present the results of RPG session to the players. The result presentation was aimed to get farmers' response to the proposed analysis in the form of simple graphs of the land-use dynamics, water exchanges, and incomes.

3.8 MAS modeling

The RPG was implemented into a simple MAS model using CORMAS to facilitate joint learning about resource use, interactions among different variables and their effects. Unified Modeling Language (UML) diagrams were built to identify different entities, components, and their interactions, sequential processes and modalities. Class, sequence, and activity diagrams were also built. These UML diagrams were used as a reference for building the model. The detail UML diagrams used in this study are discussed in Chapter 6. The rules used in the RPG were translated into simple lines of codes in smalltalk language and used in the CORMAS platform.

CORMAS is based on the VisualWorks software which is a programming environment based on smalltalk. It is available in the form of sets of smalltalk classes representing generic social entities encoding behavior exhibited by agents exploiting natural resources (CIRAD 2003). CORMAS platform is structured in three modules for the following purposes (Figure 9):

1. Designing specific entities: spatial, social and passive ones,
2. Specifying the sequence of task: control of evolution, and
3. Defining method of visualization: grid, graphs and exchange of messages.

Each module has specific steps to accomplish before the model is ready to run. They are briefly explained below. For more details please refer to CORMAS Tutorial 1 and Tutorial 2 (CIRAD 2002; and CIRAD 2003).

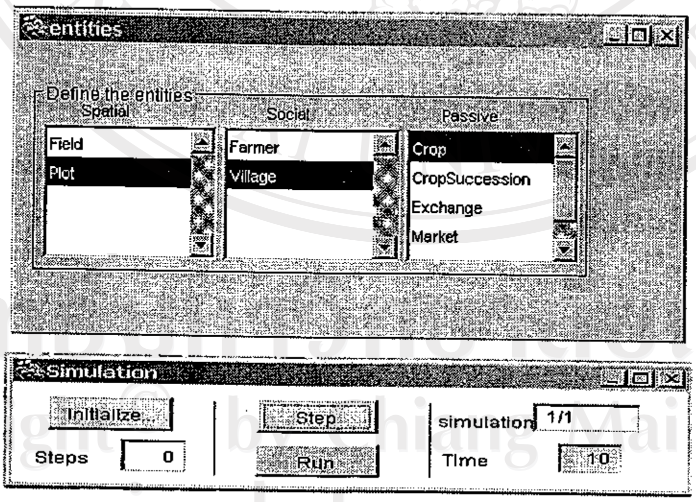


Figure 9. Structure of the main modules of the CORMAS simulation platform

CORMAS has a specific window to run simulation. The model saved in "CORMAS/models" directory needs to be loaded. Once the model is loaded, a spatial grid interface can be opened with required environment and point-of-view to visualize the simulation. Exchanges between agents can be visualized in the message window. The model has to be initialized based on selected parameters. Simulations can be run by clicking on "step" to simulate stepwise (1 time step per run) or click on "run" after inserting number of steps to allow model to simulate the assigned steps.

The simulation outputs can be exported as ASCII, MSExcel, or database files. Thereafter, data can be analyzed using any software packages. Sensitivity analysis of the model can be conducted within the CORMAS platform.

3.9 Overview of the methods

The three approaches are iteratively integrated such that they facilitate sequential flow of the information and facilitated as cumulative process of information gathering and analysis to better address the research issue. Integration of tools is also expected to facilitate analysis and achieving the objectives of the study (Figure. 3). Initially the agricultural and farming systems diagnosis helped in contextualizing the problem of water sharing, characterizing the system, and to define parameters to be used in the RPG. The RPG was built on the understanding from the first step to examine the water sharing process and observed unique behavioral patterns. As RPG has limitations to handle complexities and its use is constrained by time, CORMAS platform helped to model and simulate of different scenarios to refine our understanding of the processes. The following chapters present the findings of each approach and finally consolidate them into a general conclusion and recommendations of the study in the last chapter.