ON-FARM CONSERVATION AND USE OF LOCAL CROP DIVERSITY:

Adaptations of Taro (*Colocasia esculenta*) and Rice (*Oryza sativa*) Diversity to Varying Ecosystems of Nepal

By

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PhD Thesis

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Abstract

This thesis compares farmers' and researchers' interpretation of ecological adaptation based on studies of farmers' knowledge associated with taro and rice grown under varying temperatures and moisture regimes. Farmers' knowledge was acquired through different socio-metric techniques and household surveys. The scientific basis of farmers' knowledge was examined through field testing and laboratory analyses. Wide and narrow adaptation of taro cultivars was experimentally tested at different altitudes and cultivation practices. Similarly, rice varieties were tested reciprocally under different moisture regimes, independent on agro-ecological zones.

The persistence of crop diversity and local knowledge are primarily affected by environmental factors. Compared to stress environments more diversity and knowledge persist under favourable environments. Similarly, the amount of diversity was always high where improved and traditional varieties were grown together. The richness of diversity and the amount of local knowledge that farmers hold are directly related. In the Mid Hills where varietal diversity was rich, farmers' knowledge was also rich.

Farmers distinguish rice environments by 'names' created after distinct descriptors. Farmers' bases for naming rice environments include i) the availability of irrigation water for their plots, ii) the landforms in their location, iii) location in relation to the irrigation canal, iv) the sources of irrigation water, stream or glacial melt water, and v) the environments distinguished by growing season. Similarly, the ways farmers distinguish and measure crop diversity at different locations and local languages was found similar. At the same time crop varieties are identified by i) a secondary name if the primary name alone does not adequately distinguish it, ii) the name of the place from where the particular variety was introduced, iii) nickname(s) created after the most popular variety of the locality if the introduced variety has similar traits, v) traits that characterise their specific adaptation, and vi) traits specifically related to local uses. However, farmers recognise the same variety or population with different names or 'nicknames' grown in different localities. The results of reciprocal experiments revealed that the expression of distinctive traits is affected when farmer-named taro or rice varieties have been grown away from their origin for a significant period of time. The study concludes that 'names' distinguish diversity better when they are created after inherited traits that are least affected by environment and/or management factors.

The studies show that food traditions are closely linked to richness of crop diversity. Some varieties are preferred for specific dishes whereas other varieties are used for other types of dishes. The likelihood of crop landraces being conserved increases if: a) they are competitive relative to other options farmers have, b) farmers and consumers follow socio-cultural norms, and c) traditional dishes still remain popular. Thus diversity of use can enhance diversity conservation on-farm.

In contrast to the existing tradition of growing altitude specific taro cultivars, this research shows that taro cultivars regardless of their origin can be grown widely across altitudinal gradients. However, their performance differs by botanical variety. The cultivars that produce corms performed better at warmer places, while those that produce cormels perform better in

their origin regardless of temperature. Tuber yield and their qualities are affected by cultivation practice. Taros planted into deep furrows with irrigation and fertilizers always produce higher yields compared to taros planted with the traditional flat methods. When grown in deep furrows, corms stretched longer, but their radius was decreased. Corm length of cultivars that produce long corms decreased when grown with the traditional flat planting method.

In rice, wide and narrow adaptations of improved varieties and landraces differed over locations. In the **High Hills**, the improved variety Zhingling 78 outperformed all landraces under ‘favorable’ as well as ‘stressed’ environments. The landraces originating at the higher elevations performed better than those coming from lower elevations, especially under temperature stress. Despite high yields, the improved variety was more affected by cold-water stress than all the landrace populations. In the **Mid Hills**, some landraces traditionally cultivated in ‘favorable’ environments, performed better than improved varieties and those coming from ‘stressed’ environments especially under moisture and fertility stress, showing wider adaptability. By contrast, rice landraces traditionally grown under moisture stressed environments showed poor performances under more favorable environments, indicating specific adaptation. Unlike the improved varieties, all landraces were found to be sensitive to day length and therefore do not fit in environments where the rice growing seasons differ in terms of day length. The upland landraces matured extra early in all ecosystems. On the ***Tarai*** **plain**, higher grain yield was obtained from rain fed lowland than from irrigated ecosystem. As farmers elaborate, results of soil analysis also proved that soils in rain fed areas had richer nutrient content and looser texture which are favored for high yield. The landraces and the improved varieties differed with respect to maturity duration, plant height and response to day length. Compared to landraces improved varieties grew well across all production environments. This research categorically identifies that i) some landraces coming from favorable environments can be grown more widely across different ecosystems; ii) landraces coming from temperature and moisture stressed environments have a high degree of localized adaptation, and iii) improved varieties can be grown widely under both stress as well as favorable environments.

There was a high degree of correspondence between farmers and researchers in distinguishing soils, ecosystems and crop diversity. Because farmers cultivate crop varieties only under specific environments this limits their knowledge of wide and narrow adaptation. Greater understanding of the adaptability of crop diversity and farmers’ management strategies provides a foundation for future research, development and conservation. The integration of local knowledge into research will help fine-tuning formal research together with the conservation of ecosystems and crop diversity on-farm.

SAMMENDRAG

Med basis i studier av bøndenes lokalkunnskap om taro og ris dyrket under forskjellige temperatur og fuktighetsforhold, sammenlignes bønders og forskeres tolkning av økologisk tilpasning. Sosio-metriske metoder og intervjuer på husholdsnivå ble brukt til å fange opp den lokale kunnskapen. Vitenskapelig basis for lokalkunnskapen ble undersøkt ved feltprøving og laboratorieanalyser. Taro ble testet for vid og snever adaptasjon ved feltforsøk på ulike høydelag og ved ulik dyrkingspraksis. Ogsa rissorter ble prøvd under ulike fuktighets regimer uavhengig av agroøkologiske soner.

Sortsvariasjon og lokalkunnskap påvirkes av miljøfaktorer. Sammenlignet med områder der jordbruket er begrenset av økologiske stressfaktorer var det mer diversitet og mer lokalkunnskap i områder med gunstige jordbruksforhold. Det var også mye diversitet i områder der det ble brukt både moderne og tradisjonelle sorter. Det var en klar sammenheng mellom diversitet og lokalkunnskap. I områder med mye sortsvariasjon var også lokalkunnskapen rikere.

Risdyrkingsmiljøene gis navn i forhold til bestemte faktorer, som i) tilgang på irrigasjonsvann, ii) topografi, iii) lokalisering i forhold til vanningskanalene, iv) vannkilde, elv eller bresmeltevann, og v) aktuelle dyrkingsperioder på stedet. Bønder på ulike steder og med ulike språk beskrev sortsmangfoldet med de samme kriteriene. Sortene hadde et sekundært navn hvis det primære navnet ikke identifiserte sorten klart nok. Ellers var sortene identifisert ved navn på stedet der sorten var introdusert fra, oppkalling etter en kjent sort med lignende egenskaper, spesifikk adaptasjon, og egenskaper som knyttes til lokal bruk. Men den sammme sorten kan ha ulike navn ved dyrking på ulike steder. Dyrkingsforsøk viste at distinkte karrakterer påvirkes når bøndenes sorter av taro og ris dyrkes på andre steder enn der de har sin opprinnelse. Det konkluderes at navnene identifiserer sortene klarere når de reflekterer egenskaper som påvirkes minst av miljø eller dyrkingspraksis.

Noen sorter foretrekkes til bestemte matretter. Det var derfor en klar sammenheng mellom mattradisjoner og sortsvariasjon. Sannsynligheten for at en landsort blir bevart øker hvis a) den er konkuranseedyktig under bondens ulike valgmuligheter, b) bøndene og konsumentene holder sosio-kulturelle tradisjoner i hevd, og c) når tradisjonell maktkultur er usvekket.

I kontrast til tradisjonen med å dyrke høydespesifikke tarosorter, viste undersøkelsen at tarosortene kunne dyrkes på tvers av høydesoner uavhengig av opprinnelsen. Men avlingsresultatene påvirkes av sortstype. Sorter som danner rotstengel gjorde det bedre i varmere klima mens sorter som danner greina rotstengler gjorde det best på opprinnelsessted uavhengig av temperatur. Avling og avlingskvalitet påvirkes av dyrkingsmåte. Taro som plantes i furer og med irrigasjon og kunstgjødsel gir høyere avling enn taro som dyrkes på flat åker. Når taro gror i furer strekker røttene seg lenger men blir tynnere i radius.

Vid og snever adaptasjon varierte mellom lokaliteter for både landsorter og moderne sorter av ris. I den høyeste høydesonen gjorde den moderne sorten Zhingling 78 det bedre enn alle landsortene enten vekstvilkårene var gode eller preget av stress. Landsorter fra høyre høydesoner gjorde det bedre enn de fra lavlandet, særlig under forhold med temperaturstress. Men til trosss for høye avlinger reagerte de moderne sortene sterkere på kaldtvannsstress enn landsortene. I den midtre høydelag gjorde noen av landsortene fra gunstige dyrkingsmiljøer det bedre enn moderne sorter og landsorter fra stressmiljøer. Dette var særlig tydelig når

sortene ble testet med mangel på fuktighet og plantenæring, noe som tyder på vid tilpassing. Sorter fra områder med tørkestress gjorde det dårlig under gunstige vekstvilkår. Det tolkes som snever tilpassing. I motsetning til de moderne sortene var alle landsortene daglengdesensitive og kunne derfor ikke dyrkes på forskjellige årstider. Landsorter fra tørrlandsforhold modnet særlig tidlig i alle økosystemene. På lavlandsslettene ble det oppnådd høyere avling ved dyrking under naturlig oversvømmelse enn ved bruk av irrigasjon. Både bøndenes oppfattninger og de kjemiske jordanalysene viste at de ikke-irrrigerte arealene hadde bedre innhold av plantenæringsstoffer og gunstigere jordtekstur. Landsorter og moderne sorter var ulike med hensyn til tidlighet, plantehøyde og daglengdereaksjon. Sammenlignet med landsortene vokste de moderne sortene bedre på tvers av dyrkingsmiljøer. Det konkluderes med at i) landsorter fra gunstige miljøer kan dyrkes videre på tvers av ulike dyrkingsmiljøer, ii) landsorter fra steder medc tørke- og temperaturstress har en høy grad av lokalisert titlpasning, og iii) moderne sorter kan dyrkes vidt under stressforhold så vel som under mer optimale dyrkingsforhold.

Det var godt samsvar mellom bondekunnskap og vitenskapelige funn med hensyn til klassifisering av jord, økosystemer og sortsvariasjon. Siden bøndene dyrker sine sorter under bestemte forhold er deres kunnskap om vid og snever tilpassing begrenset. Forståelse av sortstilpassing og bøndenes forvaltningsstrategier gir bedre grunnlag for framtidig forskning, utvikling og bevaring av plantegenetiske ressurser. Lokalkunnskap kan bidra til a finstemme forskningen med behov for økosystemforvaltning og bevaring av sortvariasjon i jordbruket.

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Deepak Kumar Rijal

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CHAPTER 1: INTRODUCTION

This research documents local knowledge about the diversity of taro and rice maintained under traditional systems and ecological niches. Results are presented of wide and narrow adaptation experimentally tested for traditional varieties of i) taro under different altitudes and management practices, and ii) rice across moisture regimes independent of high, mid and low altitude areas. This research investigates the scientific basis behind farmers' knowledge related to taro and rice. The importance of diversity and farmers' knowledge for sustainable agriculture is highlighted. The policy implications of key findings are discussed. The context, research questions, research hypothesis and structure of the thesis are described below.

1.1 The context

Local knowledge is often compared and contrasted with the scientific knowledge. Since this research examines the scientific basis behind local knowledge, further elaborations are required to make distinctions between these knowledge systems. The distinctions are related to the processes and the actors involved in creating this knowledge. The knowledge and information created through conventional research are considered scientific while those hold by farmers as local knowledge. Scientific knowledge is produced through systematic research with prior defined methods and objectives. The knowledge held by custodian farmers, created by their experience or inherited from their ancestors, relatives and friends is called local knowledge. Local knowledge denotes 'locality', which represents local situations (Kloppenberg, 1991). This knowledge is 'local' in the sense that it is derived from the direct experience of a labour process which is itself shaped by the distinctive characteristics of a particular place. Local knowledge is continually being produced and reproduced by farmers and agricultural workers. These knowledge systems are sometimes described in terms of their potential adaptations. Dewelt (1994) characterises indigenous knowledge systems (IKS) to be mutable immobile[1] whereas scientific knowledge systems (SKS) as immutable mobiles[2]. SKS and IKS differ in a number of ways such as specialised vs. holistic, use of high inputs vs. low inputs, market risks vs. environmental risks, profit goal vs. subsistence and cultural disjunction vs. cultural compatible. Thus the local and scientific knowledge can be distinguished by a) the processes through which knowledge is produced and reproduced; b) the context and dimensions they encompass; c) the scale and extent they are adopted; d) the extent they potentially adapt over a wide environments and e) the degree to which local and scientific knowledge complement each other.

Despite gradual recognition of the processes involved in producing ‘local knowledge’, scientific methods have been considered to be the most consistent means of producing reliable knowledge. Science often produces specialised knowledge based on prior-defined theories. Scientific knowledge is often reductive and may not adequately adapt to complex systems. For example, Nepalese agriculture constitutes a complex system in which farmers rely on science-based technology as well as on traditional practices. Thus the process through which scientific knowledge is produced differs than for localised knowledge. However, the scientific basis of farmers’ knowledge has not been adequately researched before.

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[1] that is contextualized, holistic knowledge that can be adapted and applied to similar phenomena in other circumstances

[2] information that can be transferred without transformation to any spatial or social location (Latour 1986:7-14)

1.2 Research approach and adaptation

Plant adaptations are determined by genotype, the environment and the extent to which these interact. Adaptations are affected by several natural and human managed factors. The research approaches through which individual cultivars have been developed affect their adaptation. In conventional research, adaptations are assessed under a pre-defined environment using different methods. Unlike ecologists who prefer a 'common garden' experimental approach, crop breeders conduct multi-location trials. Crop varieties are tested under target ecosystems distributed across a wide geographic area. In conventional research adaptations of wheat and rice diversity are assessed under broadly described environments and ecological regions (e.g. Rajaram *et al*., 1997; Witcombe, 2001). In conventional plant breeding, research objectives have been to develop varieties suitable primarily for specific ecosystems. Accordingly, crop varieties are promoted based on their overall performance and those with adaptations to a specific environment or niche are often discarded. Therefore, the environment and location specific problems are not fully addressed by conventional research. Decentralized plant breeding has recently emerged to address problems of location-specific environments and needs. Until recently research methods assessing both wide and narrow adaptation have not been widely used by national research programmes. Therefore, the adaptations of crop varieties often remain unclear.

In traditional systems, varieties are developed through selection by farmers in their local environment. Similarly, growing environments for introduced varieties are selected according to the information coming along with the planting materials, the knowledge already held by the cultivators, and the information derived from seeds of their parent crop varieties. Unless otherwise reported, experience shows that farmers rarely grow introduced varieties under varied environments to determine their adaptability. Such varieties are only grown under a representative farm environment. Nepali farmers claim that they have categorically identified suitable rice (Chapter 7; Soleri *et al*., 2002) and taro cultivars (Chapter 5) for different environments. Farmers disseminate ecological information whenever available through local networks. The success and / or failure stories are quickly disseminated among the farmers. The technical messages derived from failure cases are shared among local farmers faster than the success stories. Rana (2004) reported that Nepali farmers share any failure cases or striking information quickly as a precautionary measure. Thus farmers manage their resources through distinctive methods.

Although variety selection under traditional systems and formal research seems similar, methods through which plant breeders generate information, the units they use to interpret this information, and the scale they articulate this information are different than from the traditional system. Unlike modern varieties that are grown with high external inputs such as fertilizers, most traditional varieties are grown under low input conditions. Since improved and traditional varieties[i] are developed through distinct processes, their areas of adaptation could be different. In both scientific and traditional systems, genotypes and cultivation techniques are explored largely for specific adaptation. Their potential expressions under varying environments are unknown. The degree of expression might differ by crop species. To assess wide and narrow adaptation of taro and rice diversity, field studies were conducted under varying production environments. The research question is therefore, are local varieties limited to the specific ecosystems or niches they are currently grown in, or is it through the lack of knowledge and experimental research that these varieties are not more widely planted'? The specific questions include:

- Do local taro and rice varieties have the potential to grow under varied local conditions?
- Do improved rice varieties grow in ecosystems other than those recommended for?

- Does existing crop diversity relate to adaptation and local uses?
- Are there certain traits that prevent landraces growing away from their traditional habitats?
- If so could this be an additional management strategy to support the maintenance of crop genetic diversity on-farm through enhanced use.

If these questions are addressed this work provides a foundation for the management of diversity on-farm.

1.3 Rationale and research hypothesis

Adaptations of root crops such as taro differ from crop propagated by seeds. In Nepal, taro research has been initiated only recently and therefore improved varieties have not yet been identified and released for general cultivation. Apart from reports that taro species have wide adaptation, Nepali farmers have been growing different local varieties across agro-ecological zones and ecosystems within the same zone. Different methods and cultivation practices are evident for taros between agro-ecological zones and ecosystems within the same zone. As a result of inadequate research, understanding of wide and narrow adaptation of taro varieties across temperature and management regimes remains unknown.

Unlike taro, several rice varieties have been released for defined ecosystems of individual agro-ecological zones. In conventional research, adaptations of rice varieties are assessed especially under high input conditions; their potentials under traditional ecosystems are therefore unclear. Scientific literature documents that improved varieties have wider geographic adaptation compared to traditional varieties. The general perception has been that improved varieties grow with external input, while traditional varieties are chosen for marginal environments and niches. Evidence shows that some traditional varieties grow very well under high input while some improved varieties successfully grow across a wide range of environments.

Past studies explored knowledge associated with the ecosystem's individual components, research that documents knowledge generated by interaction among ecosystem components has therefore been limited. Scientific studies that assess wide and narrow adaptation of traditional varieties of taro and rice under varying ecosystems have begun in the recent past. Through this research the adaptedness of selected taro and rice varieties had been experimentally tested. This research empirically tests the following hypothesis:

i) farmers hold specialized knowledge about traditional varieties cultivated under localized environments or niches,

ii) farmers' selections of ecosystems or niches for traditional and introduced crop varieties differ for crop species that have different breeding and reproductive systems,

iii) farmers take decisions about their crop diversity based on fully acquired knowledge and information inherited from their ancestors, relatives and friends as well as created on their own,

iv) taro varieties traditionally cultivated under specific agro-ecological zone and ecosystems have localized adaptation; performance decreases when grown away from their traditional habitat(s),

v) local rice varieties that are grown with low inputs under narrow geographic area have localized adaptation,

vi) improved rice varieties can be grown widely under varying moisture and fertility regimes and wide geographic areas,

vii) improved and local crop varieties have developed specialized adaptation and therefore performance decreases when grown away from their traditional habitat(s).

Understanding how farmers interpret adaptation of these two crops to different environments first requires (i) an understanding of how farmers perceive and describe the ecosystems in which these crop varieties are grown, (ii) understanding the ways farmers describe and distinguish diversity they cultivate, (iii) the ways farmers describe variety adaptation to different ecosystems they manage, and iv) the ways crop varieties are linked to adaptation and local uses. Enhancing the use of this information from farmers requires the technical assessment of the basic parameters of the farmers' plots (soil, moisture regime, temperature), an analysis to the diversity of the varieties the farmers are growing, and experimental evaluation comparing the adaptedness of these varieties in their traditional and outside environments.

1.4 Structure of the thesis

This research was conducted in three districts covering from 80m to 2250m elevation changes in Nepal. General descriptions of these three sites are found in Chapter 2. Information from one site, the high elevation site, is limited to one year of field data, as the area thereafter became unsafe due to political conflicts and Maoist violation. Chapter 3 contains a discussion of the overall methodologies used within this thesis; specific details of data collection and analysis are found in the individual following Chapters.

Farmers' descriptions of their ecosystems are described in Chapter 4; in particular farmers' descriptors for soil types were compared to standard experimental descriptors. Chapters 5 and 6 respectively contain descriptions of taro diversity found in farmers' fields and dishes used in the local diet. Chapter 6 assesses the link that prevails between food culture and taro diversity. It analyses ways of increasing demand for traditional dishes through improved processing and recipe development. Chapter 7 describes varietal diversity of rice found in farmers' fields. Chapter 8 contains a review of adaptation and adaptedness of crop varieties, followed by a discussion on ways farmers and researchers elaborate adaptation. It discusses the researchers' views on adaptation, and the reasons why these differences occur.

Experimental results are found in Chapter 9 for taro and Chapter 10 for rice. Chapter 11 contains a discussion on how this study contributes to knowledge about conservation of agricultural biodiversity on-farm and provides founding information for future research and development policies. The implications of this research with respect to biodiversity management and livelihoods are elaborated. The policy implications of this research are discussed.

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[i] Here a crop **variety** indicates a distinctly named crop population as commonly understood by general users. Crop varieties and their derived populations are termed **local** or **traditional varieties** which i) were developed through farmers' selection over time, ii) have been cultivated by farmers for decades and iii) are not officially recommended for general cultivation by formal institutions. Whereas varieties developed by Commodity Research Programmes are called **improved** or **modern** varieties**. Cultivar** refers to both traditional and improved varieties.

CHAPTER 2: BACKGROUND OF NEPAL AND SITE DESCRIPTION

This Chapter provides general background on the country and the individual study areas where this research was conducted. An overview of the country with respect to physiographic, climatic and ethnicity distribution is presented. The rationale for the selection of individual study areas is discussed and natural and socio-economic contexts described. The extent and distribution of crop diversity for each of the study areas are elaborated. Farmers' perceptions of livelihood options from individual study areas are provided as background information.

2.1 Physiographic description of Nepal

Nepal is a landlocked country located in South Asia between India towards the south and China towards north. It lies between 20° 22" and 30° 27" north, and longitude between 80° 45 and 88° 12" east has an area of 141,181 km². Nepal is very diverse with respect to geographical, climatic, ethnicity, religion, culture and languages. Similarly, social norms and values including foods traditions are adapted to local conditions, which might relate to crop diversity and local environments.

Nepal is a country of diversity in terms of geographical, bio-physical and climatic factors. Elevations range from the *Tarai* plain (from 70m) in the south to up to the highest peak of the world (8800m) in the north. The existence of mountains, hills, ridges, and low valleys has resulted in ecological variations. Nepal can be divided into three main physiographic regions: i) the mountains, ii) the middle hills, and iii) the *Tarai* plain, which are often dissected by river systems. The physiographic regions of Nepal within which this research was also conducted, are described below.

2.1.1 Mountain region

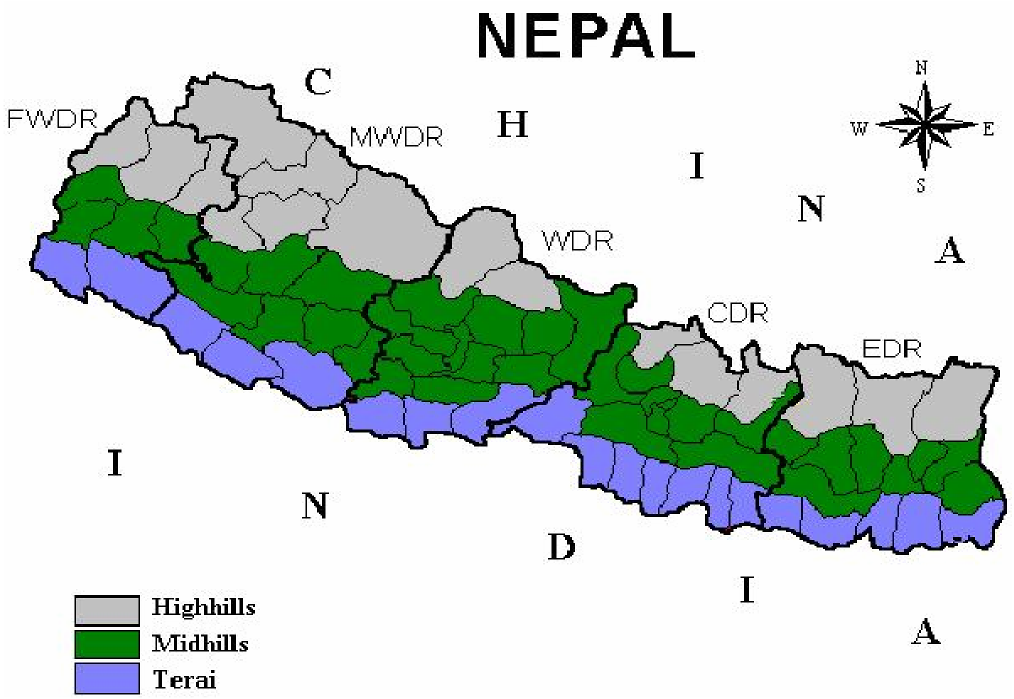
This region is situated 4000m asl. It has a rugged topography and human activities are minimal, being sparsely populated. Peoples' livelihoods here depend upon the age-old trans-human systems, trekking and small scale farming. Since mountain regions have limited arable lands, this research was conducted at lower altitude areas where agriculture significantly contributes to livelihoods. This region occupies about 19% of the total land area of the country.

2.1.2 Middle hill region

The hill regions are between 1000 and 4000 m asl. It is further sub-divided into the *Mahabharat lekh*, *Siwalik* range and several river basins and valleys. This region accounts for about 64% of the total land area. To its south lies the lower *Churia* range whose altitude varies from 610 meters to 1524 meters. Despite heavy emigration, the hill region comprised the largest share of the total population in 1991. The lower hills and valleys are densely populated. The livelihoods here are primarily dependent on agriculture cultivated under a traditional system.

2.1.3 *Tarai* region

The *Tarai* plain stretches towards the Indo-Gangetic plain and the altitude ranges from 70m up to 1000 meters. It contains some productive valleys and inner valleys including the Chitwan, Dang and Surket of the western *Tarai*. The term *Tarai*, presumably derived from Persian, means "damp", which appropriately describes the region's humid and hot climate.



Map: 2.1 Physiographic and development regions of Nepal.

The lowland *Terai* region, which has a width of about 26 to 32 kilometers and an altitude maximum of 305meters, occupies about 17% of the total land area of the country.

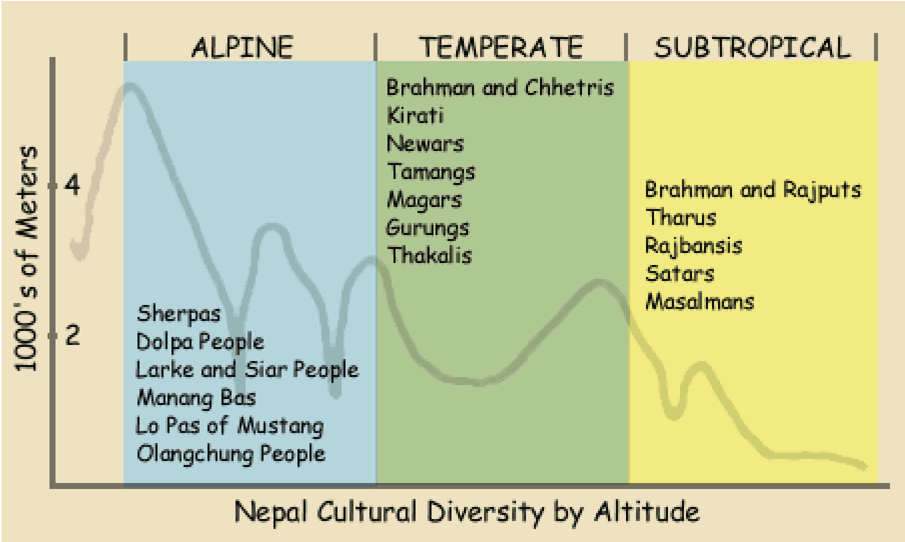
2.2 Climatic distribution

Nepal has a greatly diverse climate created due to altitudinal variation. Sthapit and Bhattarai (1989) describe five climatic zones for Nepal according to altitude, rainfall and temperature. Its major climatic zones include; i) tropical and subtropical zone distributed below 1200 meters, ii) cool, temperate zone roughly distributed between 1200 and 2400 meters, iii) cold zone distributed between 2400 to 3600 meters), iv) sub arctic climatic zone distributed within 3600 and 4400 meters), and v) arctic zone found above 4400 meters (adopted from the internet).

The term monsoon is synonymous with the rainy season which starts from early June and lasts through to September. Above 70% of the total precipitation is received during the monsoon season. The amount of precipitation differs from one geographic region to another and from east to west. The eastern regions are wetter than the west. However, the western regions receive more precipitation during the winter season than the east. Similarly, the country provides excellent habitats for plant and animal species that have local, regional and global importance. For generations farmers have been the custodians of this diversity and knowledge, especially where the effects of technological interventions are minimal. Investigating botanical and ecological knowledge related to traditional crop diversity requires characterization of custodian farmers.

2.3 Population and ethnicity distribution

The census shows a population size of 23.1 million with an annual growth rate of 2.2% (CBS, 2002). The greater proportion of the total population reside in the mid hill region followed by the *Tarai* plain and the lowest in the mountain region. This distribution is related to the access to natural resources such as arable land. Nepal has over 40 different ethnic groups settled under different geographic regions. The following figure shows the distribution of distinct ethnicity by altitudinal gradients. The people living in the mountain region are different from those from the hills and on the *Tarai*.



Source: www.visitnepal.com/nepal

However, the ethnicity distribution across study areas is slightly different than what above figure generally describes. *Chhetris* are the predominant ethnic group of the high hills, *Bramhin* in the mid hills and *Tarain* on the *Tarai* plain. The distribution of ethnicity across wide geographic region and the ecosystems they cultivate are linked to farmers' maintenance of crop diversity on-farm.

Over years, the rate of emigration from hilly regions (permanent or seasonal) has increased along with the rapid development of infrastructure (road links) towards the *Tarai* plain. Local knowledge and planting materials are carried up and down during emigration, which affects crop diversity on-farm. The amount of resources transferred depends upon characteristics of the emigrating population. Local communities whose livelihoods are fully dependent on traditional systems transfer a greater amount of plant materials and associated knowledge than households dependent on non-farm activities. Thus emigration potentially affects the extent and distribution of diversity and knowledge.

2.4. Location and climate of study area

Individual sites were selected that represent agro-ecological diversity, the amount and diversity of target crops as well as the effects of change due to research and extension including access to roads and markets. This research was conducted in the Kaski and Bara districts from the mid hill and onto the *Tarai* plain areas of Nepal (Map 2.1). These districts are representative of agro-ecological conditions as well as taro and rice diversity of the areas. The districts are also representative with respect to infrastructure and government services. The infrastructure encompasses the provision of transportation, market and irrigation facilities. Based on the above criteria Begnas and Kachorwa villages were selected from Kaski and Bara districts, respectively. Initially Jumla, from western high hills, was also selected for this research. The site had to be closed because of on-going political conflict. Despite conflicts field experiments were accomplished at least for one year. The detailed socio-economic studies carried out in the Kaski and Bara study areas are presented.

Map 2.2 Map showing high hill, mid hill and *Tarai* plain study areas, Nepal.

Climates across the study areas are highly variable. The high hills are classified as temperate to alpine, while the mid hills have a warm temperate to sub-tropical climate. A sub-tropical climate is found on the *Tarai* plain. The mean air temperature decreases with increasing altitude. The mean temperature increase between high and mid hills was 6 ºC, and between mid hill and *Tarai* plain it was 9 ºC. The mean air temperature during a cropping period varied among the study areas. The mean annual rainfall at three sites was highly variable. The highest rainfall was recorded at the mid hills, followed by the *Tarai* plain and the high hills (Table 2.1).

Table 2.1 Agro-climatic descriptions for high hill, mid hill and *Tarai* plain areas in Nepal.

Parameters/AEZ#	High hill (Jumla)	Mid hill (Kaski)	*Tarai* plain (Bara)
Altitude (m)	2240-3000	600-1400	80-90
Latitude (dd.mm.ss)	82° 05' 00" to 82° 10' E	28° 7' 35"N to 28° 11' 55"N	26° 52.63' N to 26° 54 N
Longitude (dd.mm.ss)	29° 12' 30" E to 29° 20'"	84° 06' 1" E to 84° 09' 50" E	85° 08.13' E to 85° 10' E
Position of site in regional topography	Mid Western Development Region, 6 km west from Jumla airport	Western Development Region, 16 km east from Pokhara municipality	Central Development Region, 23 km southeast from the district headquarter
Annual rainfall (mm)	866	3979	1515
Monthly rainfall (mm)	72	332	126
Daily min. temp. of coldest month (ºC)	-4.4	7.0	8.5
Daily max. temp. of hottest month (ºC)	21	31	35
Monthly temp. (º C)	12	21	25.6
Agro-ecological zones classification system	Arctic, alpine, sub-alpine, warm temperate, cool temperate	Upper sub-tropical to warm temperate	Sub-tropical

Source: Sthapit, Upadhyay and Subedi (1999). #AEZ: Agro-ecological zone. Agro-climatic classification adopted from Sthapit and Bhattarai (1989).

2.5 Socio-economic characteristics

The results of socio-economic surveys previously carried out, are provided as background information. The size of land holding, the extent of land fragmentation, farmers’ access to irrigation water, the amount of external inputs used, and the use of improved varieties were different from one study areas to the other. These study areas differ with respect to the distribution of ethnicity and the food sufficiency months estimated at household level. Most mid hill farmers produced inadequate food to meet their household requirement, whereas over 76% of the *Tarai* households produced surplus food.

The size of land holding per household is higher on the *Tarai* plain than at mid hill. The number of parcels per household is intermediate at mid hill and the lowest on the *Tarai* plain. The average cultivable land per household is marginally lower in mid hill (0.65 ha) than on the *Tarai* (0.74 ha). In addition to socio-economic factors, farmers may hold distinctive knowledge speaking different languages. Apart from a common national language across all study areas, Bara farmers primarily communicate in the regional language.

Table: 2.2 Socio-economic characteristics of survey households

Variables		Kaski, Mid hill	Bara, *Tarai* plain
Total number of households		941	914
Sample households (Baseline studies)		206	202
Well being category (no. HH)	Rich	77	21
	Medium	74	73
	Poor	55	108
Labour force	Female	1.26	1.73
	Male	1.18	1.44
Land holding (ha/HH) by ecosystems	Ghaiya	0.03	-
	Tari	0.30	-
	Sinchit	0.21	-
	Ucha	-	0.39
	Nicha	-	0.54
Land parcel (no/HH)		3.83	3.74
External inputs use (t/ha)	Improved	0.52	0.15
	Landrace	0.47	0.13
Soil productivity *	Good	128	76
	Medium	177	62
	Poor	142	49
Varietal productivity (t/ha)	Improved	2.75	2.37
	Landrace	2.04	2.34

Source: Household survey (1998), * Total may exceed number of respondents because of multiple answers, HH= Household

The extent of improved technologies used differed by study area. In the mid hill, farmers apply higher amount of external inputs to their rice crop than from *Tarai* plain. Regardless of variety types, all rice farmers apply similar amount of external inputs. The majority of the *Tarai* farmers consider their soils as fertile while mid hill farmers have different opinions on whether their soils are fertile or infertile. In the discussion farmers stated that soil productivity depends upon the availability of irrigation water (Table 2.2).

2.6 Livelihood options in study areas

In the study areas livelihoods are dependent primarily on agriculture. Table 2.3 presents different livelihood options by wealth category of farmers from the Jumla, Kaski and Bara sites. Food crops, livestock and horticulture are important livelihood options across all sites and wealth categories. Forest products contribute to livelihoods especially in Kaski but are almost none in Bara and Jumla. Small scale business is considered important for Bara farmers, especially those belonging to rich and medium wealth category. In both study areas, seasonal labouring is common among medium and poorer families. In Jumla, this practice is common among wealthier households. Unlike Kaski, fruits and vegetables are considered important livelihood options for Jumla and Bara farmers (Table 2.3).

Table. 2.3 Livelihood options by wealth categories (% of total) reported by farmers of Jumla, Kaski and Bara study areas, Nepal, 1998.

Livelihood options	Study areas								
	Jumla (HH=180)			Kaski (HH=208)			Bara (HH=204)		
Wealth category	R	M	P	R	M	P	R	M	P
Food crops	37	37	49	33	35	30	45	45	41
Fruit & vegetable	14	12	8	6	7	2	23	10	2
Livestock	27	30	27	31	32	28	15	10	9
Forest products	0	1	0	1	2	4	0	0	0
Remittance/outside	4	9	13	12	14	11	0	3	2
Business	8	8	1	6	7	3	17	17	12
Seasonal labour	8	3	2	1	5	22	0	15	35
Total	100	100	100	100	100	100	100	100	100
Total households	107	158	165	222	196	144	47	163	247

Note: R: Rich, M: Medium, P: Poor; Farmer-defined wealth categories. Source: Baseline surveys (1998), HH= Household.

2.7 Distribution of crop diversity

The crop species grown across all study areas include rice, finger millet, cucumber and taro. The crop grown under specified regions includes buckwheat, barley and pigeon pea. Crop landrace diversity was the highest at mid hill and much less at high hill and on the *Tarai* plain (Table 2.4). This distribution could be linked to farming systems and local needs. The maintenance of traditional varieties and associated knowledge is linked to farmers' access to inputs, resources and technological interventions.

Table: 2.4 Diversity of crop varieties recorded under different representative research sites.

Food crop	Jumla, High hill	Kaski, Mid hills	Bara, *Tarai* plain
Rice	21	64	33
Finger millet	12	24	6
Cucumber	13	14	4
Sponge gourd	-	13	16
Pigeon pea	-	0	5
Taro	-	24	-
Barley	5	-	-
Buck wheat	6	-	-

Source: Baseline survey (1998); - not recorded.

In the study areas where food and horticulture are prime livelihood options, greater contribution comes from traditional varieties. Their contribution to livelihoods decreases with increasing farmers' access to alternative options for these landraces and vice versa. However, it is beyond the scope of this research to establish such a relationship.

2.8 Livelihood options and development indicators

Development indicators that measure standard of living have been referred for districts within which this study was carried out. The Human Development Index (HDI[1]) and the persistence of traditional diversity and knowledge have been compared if they correspond. HDI which also includes livelihood components revealed a higher value for Kaski (0.59, ranked 3rd out of 75 districts), intermediate for Bara (0.46, ranked 37th) and low for Jumla (0.34, ranked 70th) whereas the national average was 0. 47. HDI for urban areas was higher than rural areas (0.452). In the same order life expectancy index (LEI)[2] was estimated for Kaski (0.76), Bara

[1] Calculated based on three indicators: Longevity as measured by life expectancy at birth, educational attainment as a measure by adult literacy rate combined primary, secondary and tertiary enrolment ratio, and standard of living as measured by gross domestic product per capita (UNDP, 2004).

[2] Calculated based on the number of children ever born and surviving using demographic survey (UNDP, 2004)

(0.59) and Jumla (0.43). Income index was high for Bara (0.51), followed by Kaski (0.47) and Jumla (0.40). HDI and LEI followed the same order, which differed for income index (UNDP, 2004). Crop diversity and food traditions which are positively related enhance human development index (HDI) and life expectancy index (LEI). Despite low income, the mid hill farmers cultivating rich diversity were better with respect to HDI and LEI than farmers earning higher incomes who cultivate a limited diversity (e.g. at Bara). On the other hand, high hill farmers, whose incomes and diversity were always low had much lower HDI and LEI than at Kaski or Bara. This shows an increased food and cultural diversity not only enhances food and nutrition but also helps improve LEI. The analysis indicated that an improved household income does not necessarily improve nutrition and LEI. As was evident from the high hill study area, low income combined with limited diversity negatively affects the standard of living. The persistence of harsh climate and a minimal technical intervention have resulted the reduced HDI and LEI. The contribution of diversity and local knowledge to livelihoods especially increases when i) farmers access to inputs and modern seeds are minimal, ii) farmers adapt various options to meet ecosystem requirements and iii) farmers rely on a variety of livelihood options.

Increased agricultural intervention not only yields a change in household incomes, production environments but also a restructuring of the diversity maintained under traditional systems. Some of the components of HDI are related to farmers' access to and control over of resources. Along with health education and services, LEI relates to farmers' access to and control over of food and nutrition. The livelihood strategies however differ between farmers cultivating rich diversity and those relying on limited diversity. In the mid hill area where the effects of change due to development interventions are minimal, food and nutrition are secured primarily through locally produced agricultural commodities. Farmers having higher incomes as well as those cultivating limited diversity secure livelihoods through market approaches[3]. The high hill farmers whose earnings are minimal still secure food and nutrition through multiple options.

As presented in Table 2.3 the major livelihood options include i) local diversified agriculture, ii) seasonal migration, and iii) small scale business. It is important to examine if the distribution of diversity relates to development indicators. Several scholars have reported important contribution of local crop varieties to food and cultural securities, especially among small-scale farmers (Cleveland *et al*., 1994; Brush, 1986). Studies have also shown that farmers grow landraces along with high yielding modern varieties and that farmers in those cases tend to decrease their area of cultivation under landraces (Brush, 1995). Further studies are required that assess the roles of traditional diversity and associated knowledge in enhancing livelihoods.

This research focuses on documenting the state of farmers' knowledge about intra-species diversity, wide and narrow adaptation and empirically tests the potential of this diversity to expand beyond localized environments. The implications of this research for sustainable agriculture and on-farm conservation are examined.

[3] Larger scale farmers tend to specialize their commodities for market purposes and the remaining items which are not produced locally are supplied from local market places. This practice is common among wealthier households across all study areas and most farmers especially from the *Tarai* regions where farmers enjoy improved roads, markets and technical services than in rural areas.

CHAPTER 3: GENERAL METHODOLOGY AND STUDY CROPS

This chapter is divided into five sub-sections. The first summarises the outcomes of literature research with special focus on plant adaptation. In the second section, the general methodology used for this research, is described. Different participatory techniques implied to gather data on farmers' perceptions are briefly discussed. In the third section, initiatives undertaken by commodity research programmes, including decentralized plant breeding, are briefly reviewed. In the fourth section, scientific research designs used to assess adaptation and the rationale for selecting individual methods are described. The fifth section describes the research crops, their growing environments and research needs about adaptation. This section begins with the review of scientific literatures on plant adaptations along with their assessment.

3.1 Ecological adaptation

Adaptation may have different meanings to different people. The meaning for farmers may not be exactly the same as for the researchers. Also the definition of adaptation can differ among ecologists depending upon their areas of specialisation. Adaptation for a forage ecologist may be different than for a crop ecologist. Although adaptations are defined in a variety of ways, the most widely used definitions are:

- "any specialized characteristic that permits an individual to survive and reproduce is called an adaptation" (Environmental Encyclopaedia, 1994).
- "a change in physical, physiological or behavioural traits that results from some current environmental pressure, such as "adapting" to a change in temperature" (Smith, 1995).

Adaptedness is the degree to which an organism is able to live and reproduce in a given set of environments, the state of being adapted, and adaptation is the process of becoming adapted or more adapted (Allard, 1988). Others consider adaptation both as a 'condition' and a 'process'. There is a difference in the 'condition' of adaptation between individuals' results from a genetic difference which influences their growth and development processes with the environment. The 'process' of adaptation is viewed as a change in the genetic constitution of individuals as they accumulate genes or a change in the gene frequencies within the population which, better match growth and development with the environment (Byth, 1981; Clements *et al*., 1983). Adaptations may be elaborated according to the degree to which the individual populations are adapted to a variety of growing environments. The concepts of broad and specific adaptation are often used to describe the relative performance of genotypes when adaptation is evaluated in more than one environment. Broad adaptation describes the response of a genotype where superior performance is expressed across the majority of, or all environments, and specific adaptation describes a response where a higher level of performance is expressed in specific environments (Cooper and Byth, 1996).

The above definitions may not exactly be applicable to crop landraces which are the results of human selection over time and space. The working definition however, for landrace adaptation, includes the "response of plant-species / landraces to their natural and / or human managed ecosystem or habitat". Different theories have been suggested to understand the mechanism with reference to local adaptation (Vega, 1997). A key term frequently linked with the mechanism is ecological niche, a complex idea that tries to describe the fit between a species and its environments. A niche is defined as "an expression of the location and function of a species in a habitat" (Environmental Encyclopaedia, 1994). An ecological niche is not a place in the normal sense of the word and it is also much more than a species' habitat. It represents the interaction between a species and its habitat, describing both where a species lives and how it lives there. The fundamental niche refers the range a species could occupy in the absence of interference from other species, whereas the realised niche is the range to which a species is confined by competitors or predators (Beeby and Brennan, 1997).

Different crop species have been selected under given environmental factors. The role of the environment factors is understood in two different ways i) by setting the fitness function and selecting the fittest individuals, and ii) affecting the developmental process of the individual by determining the phenotype (Matyas, 1997). Adaptedness and productivity are, however, complexly inherited traits and much affected by environment; little is known about what happened genetically during the process of domestication (Allard, 1997). As a result of environmental stresses coupled with selection pressures, numerous landraces have been developed which are useful to man. Through changes in allelic frequency and directional or artificial selection, different ecotypes have been developed. Rice ecotypes adapted to cool or hot temperature, rain fed or deep water, fertile or marginal soils and to aluminium-toxicity, acidity or salinity are apparent examples. Since fitness differences among genotypes tend to be maximized under extreme environmental conditions (Pearson, 1987), adaptive variability is expected to fulfil at least two premises:

- favourable environments are correlated with higher genetic variability within and between populations, specially if they are heterogeneous, and

- adaptedness is more easily observable in less favourable environments, in which the greater selection pressure eliminates less adapted genotypes and reduces genetic variability (in Vega, 1997).

In theory, founder populations may rapidly undergo a drastic genetic modification and speciation. Owing to its narrow genetic base and drastic genetic restructuring, it is particularly a favourable position to undertake new evolutionary departures, including those that may lead to macro-evolutionary development (Mayr, 1991).

Climatic adaptation of plants involves both the genetic adaptation of the populations and the ability of individuals to buffer environmental changes through modifying their phenotypic response (Matyas, 1997). Genetic adaptation is understood as a change in gene frequency, directed toward a theoretical optimum in a given ecological situation. Adaptations to edaphic conditions can also occur rapidly in response to non-stressing conditions. Thus for instance, *Anthoxanthum odoratum* showed considerable genetic change within populations six years after a new limiting treatment had been used (Snaydon and Davies, 1982 in Vega 1997). Although scientific literature about adaptations of selected plant species are expanding, studies of wide and narrow adaptation related to crop diversity with varying breeding and reproductive systems are still very limited. Only recently, different approaches have been implied to enhance crop adaptations and diversity.

3.2 Assessment of wide and narrow adaptation

Crop breeders conduct multi-location trials while assessing plant adaptation. In wheat and rice, adaptations are assessed in multi-location trials conducted independent of environments or ecosystems, within the broadly described mega-environments and eco-regions (e.g. Witcombe, 2001). Crop varieties are advanced based on their overall performance and those with specific adaptation are often discarded. Studies have shown the selection of genotypes with greater fitness under competitive interaction with neighbours. The causes of the observed differences in fitness under intra-and inter-genotypic competition are unclear, though it has been suggested that annidation (occupation of slightly different niches by different genotypes) may be involved. This is a hypothesis that could not easily be tested by looking at the fitness of the genotypes in competition with neighbors that differed in the extent of their niche overlap (Ennos, 1985 in Ennos, 1990). Adaptedness is assessed in different ways, depending chiefly upon the background of researchers. While ecologically oriented researchers prefer reciprocal transplant experiments, and quantitative geneticists and plant breeders rely on the analysis of variance and genotype x environment interactions for consistent associations between particular genotypes and environments (Vega, 1997).

When genotypes from each habitat are reciprocally transplanted, replicates placed in each habitat, their relative performance in each environment can be measured. Reciprocal transplantation, also called “common garden” (Via, 1994), is thus an important tool in the analysis of genetic population structure for quantitative traits (Briggs and Waters, 1994; Via, 1990, 1991 in Via, 1994).

It can be hypothesized that population divergence is due to selective differences among habitats. This can be tested experimentally by comparing the performance of individuals originating from different habitats in a reciprocal transplantation. This approach could be more appropriate for testing species that have been grown over time undisturbed under certain environments or ecological niches. Unlike improved varieties, local crop varieties[1] are continuously grown on-farm under specified environments or ecological niches, which result in the development of a distinct population. Allard (1997) discusses how genetically complex are local varieties, which have been grown under ecological niches or certain environments. The range of adaptation remains unclear until genotypes are reciprocally assessed across wide environments. For example, most bred varieties developed for high inputs conditions could perform better under i) low input conditions and ii) ecosystems grown in shorter-day photoperiods. Since improved rice varieties are day length-neutral they could be grown both as short and long day crop. The wide and narrow adaptation of improved varieties is poorly understood because they are tested under particular ecosystems. The reciprocal transplant experiments where genotypes are tested for their wide and narrow adaptation provides basic information for future breeding programs.

In formal research, performance of crop varieties is tested over locations under broadly described ecosystems within the same agro-ecological zone. There could be several sub-ecosystems under cultivation Since multi-location trails are conducted under broadly defined environments, which only partially represent the environmental variation that persist within the same location.

[1] Local variety populations are highly variable, but are often identifiable and usually have local names. A local variety has particular properties. Some mature early and other late. Each has reaction to light, warm or cold, dry or wet or are strong or weak. All components of the populations are adapted to local climatic conditions, cultural practices and diseases and pests (Harlan, 1975).

Unlike conventional research, the multi-environment approach provides more knowledge and information about wide and narrow adaptation. Unlike landraces that are responsive to day-length, the multi-environment approach would be more applicable for assessing adaptation of improved varieties that are day-neutral. Since the interest of this study was to assess adaptability of traditional varieties under location specific environments, the reciprocal transplant approach was used both for taro and rice. Only recently a decentralised plant breeding approach has been conceptualised which aims to address problems of specific environment and target community (Sthapit *et al.*, 1996).

3.3 Decentralised breeding and local adaptation

On the ground that crop varieties developed by national research programs are often poorly adapted, even for recommended ecosystems, decentralized plant breeding (DPB) evolved to address this location-specific problem. DPB employs a variety of strategies that maximises the use of locally available resources. It specifically addresses problems by i) genetic improvement of locally cultivated promising landraces, ii) developing more adaptable and farmer-preferred varieties that essentially include landrace as one of the parents. Initially DPB was started for stressed environments (e.g. Witcombe *et al*., 1996). Later, this approach was successfully implemented in systems of high potential production (e.g. Witcombe, 2000). Past experience with DPB and lessons learned for future research are discussed.

Joshi *et al* (2001) monitored the spread of varieties (developed under DPB) in high hill villages of western Nepal. It became an interesting story when the varieties recommended for a target high hill environment were spread down below where this variety had not been tested by the plant breeders. When monitored the spread over 10 villages they found that Machhapuchre 3 and 9, both screened from crosses of Fuji 102 (Japonica) and a landrace Chhomrong dhan were widely grown at lower elevations. With these varieties, farmers harvested > 60% higher grain yield than traditional varieties. Although Machapuchhre 3 was recommended for high altitude areas, over time it became a popular variety at lower elevations where temperatures are more favourable. Despite this success story, the participatory plant breeding goal to overcome cold injury at high altitude (1800-2000m) was not fully addressed. Discussions with the scientists concerned revealed that farmers intentionally selected lines that yielded white grain colour virtually to replace locally grown landrace, Chhomrong dhan, with red grain. Although farmers obtained varieties with a desirable grain colour, the new variety still remained susceptible to cold injury. This implied that the high altitude farmers continued with their own landrace. As a result these improved varieties become increasingly popular among mid-hill farmers instead.

Some genotypes have the potential to grow under different environments. Since rice is a hydrophilic species evolved through alternating periods of drought and with variation in temperature, upland rice landraces are capable of growing under variable moisture regimes (Toole and Chang, 1979). The review suggests that conventional research does not fully exploit the potential of landraces and improved varieties. Innovative approaches that enhance biodiversity and sustainable livelihoods are required.

3.4 General descriptions of research methods used

Peoples' knowledge was gathered through household surveys and focus group discussions. The following categorical information was collected on research crop species: i) local ecological and botanical knowledge; ii) traditional varieties and farmers' preferred traits; and iii) scientific basis of local ecological knowledge. The research methods employed for individual studies are elaborated in corresponding chapters.

3.4.1 Participatory rural appraisal

Participatory Rural Appraisal (PRA) has been called 'an approach and method of learning about rural life and conditions from, with, and by rural people' (Chambers, 1994). In order to understand farmers' ecological knowledge, a combination of different agro-ecosystem analysis and farming system approaches was used (Conwey, 1985). To identify differences and commonalities on matters relating to peoples' perceptions, experiences, and opinions, focus group discussions were conducted. To induce effective participation, the more knowledgeable farmers belonging to the same gender and wealth categories were invited.

Since the researcher was involved from the implementation phase of the on-going project, he benefited in terms of a) identifying farmers holding more knowledge of local crop diversity, ecosystems, and cultivar specificity; b) locating sites with a rich ecosystem, niche, and local crop diversity; c) understanding farmers' ways of distinguishing ecosystems, soils and crop varieties; and d) creating an environment for the successful conduction of household surveys.

3.4.2 Household surveys

Field surveys were conducted to gather knowledge at the household level and also to examine the degree to which local ecological knowledge corresponds to scientific knowledge. The detailed techniques and rationale of household surveys were adapted as elaborated by Babbie (1990) and Fowler (1988). The household survey was conducted separately for taro and rice. The representative households from different ecosystems were randomly selected, in the mid hill region and on the *Tarai* plain. A semi-structured interview technique was used to gather local knowledge. Under the researcher's guidance, trained enumerators conducted household surveys. In Bara, very few households grew taro and farmers from other adjoining villages were interviewed. For rice a total of 175 households were interviewed from the mid hill and on the *Tarai* plain. While 70 randomly selected households were interviewed for taro. For both surveys detailed procedures are found in the following Chapters.

3.4.3 Panel assessment

The existing knowledge of taro diversity along with local uses was gathered through panel discussion. Some 11 to 18 farmers were involved in each discussion. The most knowledgeable members representative of farmers and consumers groups were selected through discussion with local leaders and background information known through earlier studies (Subedi *et al*., 2002).

A farmers' panel assessed product qualities grown under variable environments. Where possible, the same farmers' panel was involved throughout the evaluation. Prior to the evaluation, farmers were briefed on the scoring methods for assessing the level of importance using criteria identified by them. Focus group discussions were conducted for cross-validation on how,

a) ecosystem factors affect culinary characteristics of rice

b) cultivation practices affect culinary characteristics of taro; and

c) environmental factors affect post-harvest characteristics of taro varieties.

The detail procedures for the selection of panel members are found in individual chapters.

3.4.5 Experimental design

Adaptability of taro and rice has been assessed at large and small scales. The terms ‘large’ and ‘small’ scale here refer to the environmental variability governed by the temperature and moisture regimes, respectively. Adaptability of taro varieties was assessed across agro-ecological zones (large scale) while adaptation of rice varieties was assessed across moisture regimes (small scale) independent of the agro-ecological zones: whether high hill, mid hill or *Tarai* plain.

For both taro and rice, Randomised Complete Block design, described by Gomez and Gomez (1984) was used. Different plot sizes were used for taro and rice, with larger plots for taro. Experimental treatments were replicated three times. For both species, periodic observations were measured using standard descriptors. In rice, performance comparison was made on a few selected improved varieties recommended for individual ecosystems. Since there are no improved taro varieties, adaptedness was assessed with selected cultivars grown in different temperature regimes.

3.4.6 Parameters for assessing ecological adaptation

Plant ecologists consider species or varieties to be adapted when they survive and reproduce in a given set of environments (e.g. Allard, 1997). For crop species, adaptation is oriented towards productivity, which relates to the ability to live (grow), but not necessarily the ability to reproduce, e.g. horticulture crops (Vega, 1997). Crop breeders examine adaptation in relation to selected traits such as grain yield (e.g. Ceccarreli, 1987). Adaptations of wheat are assessed with respect to yield and yield attributes, especially when the breeding goal is focused on drought tolerance (Rajaram *et al*., 1997). Forage ecologists assess adaptation in relation to selected traits such as species survival, seed formation and phenological traits (Joshi *et al*., 2001), which show that researchers study adaptations using context-based parameters.

Earlier scholars reported that farmers maintain diversity to meet local needs and preferences. Farmers' selections of cultivars are associated with environmental risks (Oosterom *et al.*,1993), crop failure (Ceccarelli and Grando, 1991b) and local preferences. Since yield is the major attribute in upland rice, using grain yield as an index for adaptation to drought stress may be a reasonable approach (Atlin, 2001). The preferences vary by moisture regimes (Fisher, 1996), farming system and environmental variation. In mixed farm systems, straw yield may be important along with that of grain production (Byerlee and Hussain, 1993). Since this research objective was also to identify adaptive traits, the researchers in consultation with plant breeders and farmers decided to record observations that have ecological, economic and food values. The detail observations recorded in field trials are presented in the individual chapters.

3.5 Descriptions of crop species in this study

As mentioned earlier, this research was part of an on-going *in situ* crop conservation project in Nepal. According to their contribution to rural food and livelihood security across agro-ecological zones, taro and rice were selected in this study. Apart from their extent and distribution, the historical perspectives and local values associated with the research species are described. Taro and rice were selected because they:

i) represent different breeding and reproductive systems, and also have different physiological processes,

ii) are cultivated widely under similar growing environments,

iii) have interesting traits important for scientific studies,

iv) are maintained on-farm at different scales,

v) are related to traditional and cultural securities,

vi) are locally used to prepare various food dishes, and more importantly it is the farmers who hold rich knowledge about these crops and their growing environments.

3.5.1. Origin and distribution of taro diversity

Among food crops, taro is one of the least researched species. Past studies focused towards documentation of diversity, knowledge and their distribution worldwide. According to archaeological and evolutionary studies taro (*Colocasia* spp.) seems to have originated in South Asia (Matthews, 1995; Lebot and Aradhya, 1992; Purseglove, 1972), and was probably domesticated in Burma (Keleny, 1962, in Harlan, 1971). Archaeological evidence suggests that aroids were already used some 28000 years ago in the northern Solomon Island (Loy *et al*., 1992 in Matthews, 1998), long before Austronesians reached that area. Zeven and de Wet (1982) mention South Asia as the original home for *Colocaisa esculenta* L. Over time, this spread to China and Japan where *C. esculenta* var. antiquorum evolved (Figure 3.1). Similarly, diploid and triploid taros gradually spread eastwards including Indo-China, Japan, the Pacific, and New

Zealand. Their distribution expanded over time across geographical regions and the continents (Matthews, 1998, Kahn, 1988; Ochiai *et al*., 2001; Isshiki, 1999). The ways in which taro is used greatly vary by geographical regions and countries.

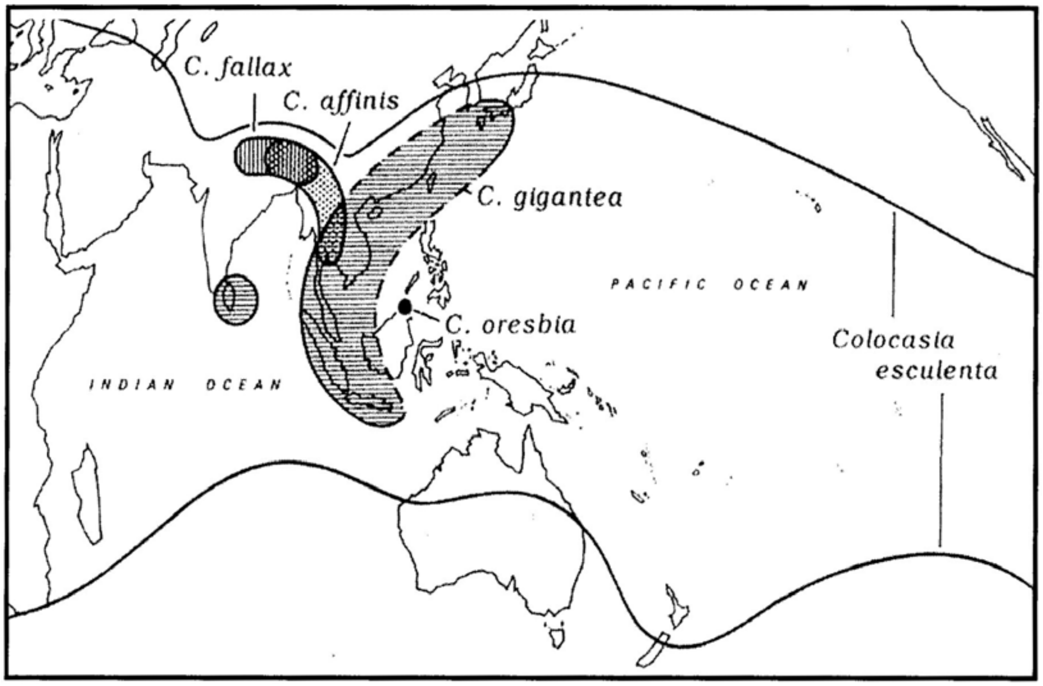


Figure 3.1 Distribution of *Colcoasia esculenta* (L.) Schott.and others (Source: Matthews, P. J., 2004).

The assessment of taro diversity, knowledge and local uses have been limited to certain region and countries. Past studies that assess diversity and knowledge associated adaptation and culinary traits have been inadequate. Empirical studies that explore the scientific basis of traditional practices, especially with regard to temperature, and management practices have been very few.

3.5.2 Origin and distribution of rice diversity

Rice is one of the most studied food crop species worldwide. Scientific literature about the origin, distribution and values associated with *Oryza sativa* is increasingly available. Vavilov (1992) stated that Asian rice originated from wild forms in the humid tropics of southern and eastern Asia. Chang (1976a) argued that Asian rice evolved from a wild annual progenitor, *Oryza nivara*, somewhere, and perhaps in several places within a broad belt roughly between 20 º and 23 º stretching from the central Ganga valley of India to the South-China sea (cf. Smith and Dilday, 2003). Its rich genetic diversity encompasses an enormous range of geographical and ecological distribution (Glover and Higham, 1996). The maps laid out by Harlan (1971), Chang (1976a) demonstrate that the extended Indo-Gangetic river basins could be the probable place of origin (Figure 3.2). Zeven and Zhukovsky (1975) reiterated that rice comes from South Asia. Today, rice is grown from 40º south to 53º north latitude in almost 100 countries (Smith and Dilday, 2003). A richer diversity of cultivated and wild relatives of rice has been documented. In Nepal alone above 2000 distinct local varieties of cultivated rice and four wild rice *Oryza* species: i) *O nivara,* ii) *O rifipogon,* iii) *O officinalis,* and iv) *O granulata* are maintained under natural environments (Gupta *et al*., 1996). A wider distribution of wild rice (Shrestha, 2002), maintenance of rich diversity under traditional ecosystems and the persistent of rich culinary knowledge associated with rice, show that Nepal lies within the region of its origin or the primary or secondary centre of diversity. Investigations regarding rice diversity, uses and their adaptation under traditional ecosystems have been inadequate, especially in areas away from their actual place of origin.

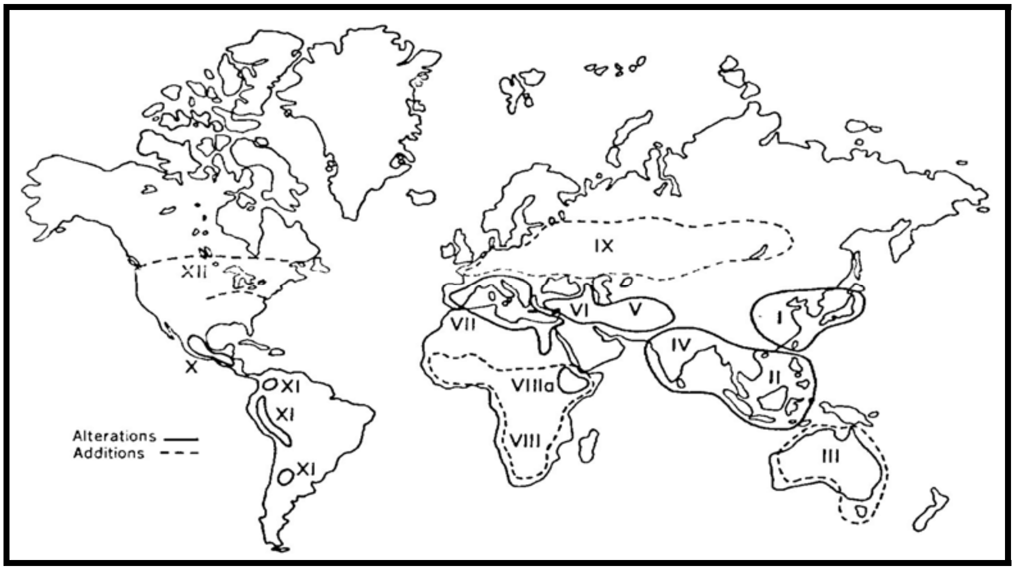


Figure: 3.2 P. M. Zhukovsky's alterations (solid lines) and additions (broken lines) to Vavilov (Source: Jack R. Harlan, 1971).

3.5.3 Distribution of taro and rice diversity

Matthews (1998) is of the opinion that taro was widespread before many modern crop varieties were dispersed worldwide. Gorman (1977) suggested, however, that rice and taros became domesticated at the same time as their wild progenitors in swampy habitats in mainland South Asia. For centuries, farmers have been playing crucial roles in domestication and dispersal of crop species. The produce of wild rice (Shrestha, 2002) and taros are considered 'pure' and acceptable for religious functions. Similar perceptions exist among local farmers of mid hill and *Tarai* plain areas of Nepal (Rana, 2004). The plant architecture, fruiting behaviour, breeding or reproductive systems, nutritional composition, and the ways in which rice and taro are used, are dissimilar. Past study has shown, however, that these species are cultivated under similar temperatures and cropping patterns; e.g. mono-crop and mixed crop (Chapter 4). The distinct characteristics associated with these species are described in Table 3.1.

Table 3.1. Botanical descriptions and uses of the study crop species rice and taro

Similarities (Taro and Rice)	Differences (Taro vs. Rice)
▪ Centre of origin or diversity ▪ distribution across agro-ecosystems ▪ existence of wild relatives ▪ ingredient of delicious dishes ▪ social, cultural & religious (pure*) ▪ growth habit (annual) ▪ colour pigmentation (presence) ▪ photosynthetic pathway (C3)	▪ propagation (vegetative vs. seed) ▪ crop duration (long vs. short) ▪ productivity (biomass & volume) ▪ uses of plant parts (all vs. few) ▪ aroma (absence vs. presence) ▪ nutritional richness (rich vs. medium) ▪ plant morphology

* Hindu text recognises these species as pure (Suddha) meaning that they are acceptable for Hindu cultural and ritual ceremonies.

3.5.4 Experimental materials used

Taro cultivars that represent botanical classes (corm, cormel), agro-ecosystem (high, mid, low altitude) and crop ecosystems (sole, mixed) were selected. The botanical classes along with their distribution are documented elsewhere (Chapter 5). Some cultivars that produce a high yield are grown by many farmers and at a large scale, while those with specific uses are grown by many farmers, but in a smaller area. Different cultivars are grown in diverse soil types (Table 3.2).

Table: 3.2 Status of taro varieties selected for field testing from Kaski, Nepal.

Local varieties /Particulars	HH	Area m²	Productivity (no. HH)			Soil types		
			High	Medium	Low	ZL	SC	Clay
Hattipow	91	58	14	63	4	12	16	4
Khari	66	104	12	51	2	16	11	3
Lahure	39	80	6	32	1	4	9	2
Kalo karkalo	33	3	5	18	1	7	5	2
Khujure	39	83	4	35	0	11	7	2
Dudhe karkalo	19	0.4	2	17	0	8	4	2
Panchmukhe	16	20	0	16	0	4	3	3

Source: Baseline survey (1998). ZL: Silty Loam, SC: Sandy Clay; HH: Household.

Rice cultivars were selected based on the extent and distribution of diversity. In the high hills, rice local varieties were collected from five different households distributed within an altitudinal range of 1950m to 2750m. In the mid hills and on the *Tarai* plain, different local varieties representing individual ecosystems with distinct traits, such as aroma, stickiness, and sheathed panicles were selected. Across all locations, some widely grown improved varieties were included for performance comparison. In terms of distribution, cultivars were selected from three categories: a) cultivars grown by many households and in relatively large areas; b) cultivars grown by a considerable number of farmers and in relatively smaller areas than (a); c) cultivars grown by few households and in small areas.

Farmers' descriptions of tested varieties with respect to status, productivity potential and yield are summarised in Table 3.3. The rice varieties for high hill were gathered from different altitudes ranging from 1950m through to 2750m above sea level of the Jumla district. Due to aforementioned reasons, local knowledge about the distribution of this diversity was not gathered. The salient features of these tested varieties are described in chapter eight.

Table: 3. 3 Description of rice cultivars selected for field testing from the Kaski and Bara sites of Nepal.

District	Cultivars	No. of Households	Area (ha)	Productivity potential			Yield (t/ha)
				High	Medium	Low	
Kaski	Rato ghaiya	5	0.07	0	4	1	1.0
	Mansara	43	0.12	0	28	14	1.31
	Kathe gurdi	47	0.10	4	40	3	2.03
	Ekle	85	0.16	16	47	2	2.26
	Rato aanadi	67	0.02	21	46	1	2.07
	Jhinuwa	5	0.01	0	5	0	1.55
Bara	Mutmur	19	0.23	2	9	8	0.05
	Nakhi saro	8	0.22	1	5	2	0.06
	Sokan	4	0.08	1	1	2	0.05
	Sathi	8	0.07	1	4	3	0.04
	Kariya kamod	na	na	na	na	na	na
	Lalka basmati	3	0.09	1	2	0	0.04
	Bhati	1	0.40	0	1	0	0.03
	Sabitri	64	0.37	31	29	0	0.06
	China 4	120	0.28	37	64	19	0.06

Source: Baseline survey (1998), na: not available.

CHAPTER 4: FARMERS' DESCRIPTIONS OF CROP ECOSYSTEMS

This chapter documents locally described crop ecosystems, soils and traits that are used to assess adaptation. It also documents farmers' perceptions of environmental factors that affect adaptation, especially the effects of temperature and ecosystem factors with a particular focus on taro and rice. This knowledge is compared with descriptions in the scientific literature. The scientific basis behind local ecological and botanical knowledge examined. The policy implications of this research are discussed.

4.1 Introduction

Unlike most other crop species, limited scientific literature is available that has studied taro genetic resources, and their growing environments. Studies of local descriptors and parameters that distinguish taro growing environments have been limited.

In scientific literature, rice is one of most well known cereal crop species. The earlier researchers studied diversity, culture and traditions along with their growing environments. In the past, studies have been limited that assess local descriptions of rice environments and their correspondence to the scientific literature. It describes growing environments using the most commonly applicable criteria for a wide geographic region. Accordingly, they are classified primarily on access to irrigation water (www.irri.org). Micro-environments are sometimes distinguished by access to sunlight, and inherent soil fertility. However, farmers have described other environments and ecological niches, not recognized in the scientific literature. For example, literature describes major environment upland or lowland. Does this correspond to the farmers' classification? Farmers' classification is compared with scientific classification to study the extent to which they correspond.

4.2 Methods

4.2.1 Focus group discussion

To gather collective response or differences on matters relating to people's perceptions, experiences and opinions, FGDs were conducted. To make the discussions more effective, only participants of the same wealth category were invited. Key informants were also selected based on their knowledge of earlier reports related to social and natural resources mapping and farmers' network analysis (Subedi *et al.*, 2002). Along with nodal farmers, diversity-minded male and female farmers were invited. Discussions were organized in order to a) identify farmers possessing more ecological knowledge; b) assess the distribution of crop ecosystems and niches; c) investigate crop diversity and d) learn how farmers distinguish ecosystems, soils and taro diversity.

Some 9 to 11 active and knowledgeable farmers belonging to the same gender and wealth category were invited to each FGD. A total of four FGDs were organized: two each at Kaski and Bara.

4.2.2 Household surveys

A slightly different sampling technique was employed for taro than for rice. Not every household grows taro on-farm. In each of the study areas, 35 randomly selected taro farmers were interviewed.

In rice, individual farms were classified according to the predominant rice ecosystem (see Table 4.3 for details). The most common ecosystems, three in Kaski and two in Bara, were selected. A total of 550 households were registered in the study areas. From each of those five ecosystems a random sample of 35 households was drawn. Thus, a total of 175 households were included in the survey. The survey addressed questions about rice environments and rice diversity.

The key areas covered included cropping system, adaptive traits, and adaptation. Farmers' perceptions of the relatedness of cultivation practices to economic traits were collected. Farmers' responses regarding the effects of ecosystem factors on product qualities were recorded. The questionnaires were discussed with enumerators, and checked through mock interviews. The questionnaires were finalized after field verification.

4.2.3 Soil sample analysis

In order to study the description of soils by farmers and researchers, composite soil samples were collected from the five predominant rice environments that prevail at mid hill and *Tarai* plain areas. Altogether 171 representative soil samples collected from 0-15cm depth were analysed for nitrogen, phosphorous, potassium, organic matter, soil pH, soil texture and soil colour at the LI-BIRD (www.libird.org) soil laboratory using standard methods (Dewis, and Freitas,1970). Farmers' perceptions data on soils were gathered from 35 households each from five pre-dominant rice ecosystems of Kaski and Bara sites. Farmers' perception data were cross-tabulated, analysed and compared with those described by the researchers. The researchers, for example describe soils using the Munsell Colour Chart (MCC, 2000).

4.2.4. Data analysis

The estimated weighted mean for individual parameters was statistically analyzed. The survey data were analyzed using descriptive statistics and the analysis of variance.

4.3. Results

4.3.1 Farmers' description of taro ecosystems

The environments in which taro is grown vary by study area (Table 4.1). Kaski farmers grow taro in open fields as a mono-crop (*swara bari*) or an intercrop or in home gardens where trees are sometimes present. These environments differ in terms of shading, soil fertility and soil moisture. Compared to open fields, darker and more fertile soils are found in the home gardens, but sunlight is often limited.

In Kaski, taro as a mono-crop is mainly grown at irregular spacing on flat fields with organic fertilisers. Plots are mulched with locally available materials, and manual weeding is performed as needed. Farmers believe that their practices are essential for producing high quality corms or cormels. Cultivars that grow vigorously and produce large corms ("Hattipow" and "Khari", for example) are grown in fertile soils, including with added fertilisers, while cultivars that produce cormels and attain shorter height are grown in less fertile soils. The "Khujure" and "Panchamukhe" cultivars are examples of this. Farmers' selection of cropping systems differs according to the purpose of production. Cultivars for home use, grown on a small scale, are often inter-cropped with other species. Those for the market, grown on a larger scale, are mono-cropped.

In Bara, taro is mainly grown as a mono-crop after rice under irrigated ecosystems. Similarly, taros grown as mono-crop are planted in deep furrows, with chemical fertilisers and irrigation. Farmers claim that taros should be grown with high inputs and in deep furrows to produce preferred corms with desirable shape and size. Therefore, deep furrow methods are chosen to produce long and attractive corms.

Table 4.1 Responses to local cultivation practices for taro in a survey of 35 households each from Kaski and Bara sites of Nepal.

Local practices	No. of farming households				
	Kaski			Bara	
	Mono-crop	Mixed crop	HG	Mono-crop	HG
Deep furrow	1	-	4	34	2
Flat planting	24	16	20		2
Irrigation (3-12 times)	1	0	0	34	1
Mulching	20	15		-	1
Organic fertilizer (t/ha)	0.47 (15)	0.08 (9)	-	-	-
Weeding	5	2	2	-	-

Source: Household survey, 2002, HG=Home Garden, Number in parenthesis indicates households, - = not reported)

4.3.2 Farmers' perceptions of plant responses to temperature stress

Traditionally, taro has been grown in a range of altitudes from the *Tarai* plain up to the high hills. As with other plant species, taro varieties are moved up and down altitudinal gradients in correspondence with trade and peoples movements. The most common kind of movement prevails when people visit their friends and relatives inside and outside villages. It is unknown however the extent to which variable temperature affects variety performance. Through discussion with key informants it was learned that high or low temperatures could affect performance of individual traits. The specific traits affected included plant survival, maturation, tuber yield, acridity, cooking and eating quality (Table 4.2). Farmers' opinion, however, varied concerning plant height. The majority of the farmers argued that plant height increases with an increase in temperature. A few farmers, however, said that plant height and temperature are, to some extent, inversely related. Farmers say that high temperatures affect corm yield and corm size. Quality traits such as color pigmentation are less affected by climatic factors. According to farmers' views, plants in open fields become greener than those grown as an intercrop.

Table 4.2 Farmers' opinions on what might happen if cultivars were to be introduced from a different crop system in a survey of 35 households each at Kaski and Bara, Nepal.

Plant response	Opinion – if cultivars introduced			
	In Kaski		In Bara	
	from mono to mixed crop	From HG to mono crop	from mono to mixed crop	From HG to mono-crop
Attractive corm	1	5	-	-
Attractive/greener	-	8	-	
Larger size corm	-	10	-	-
Larger size cormel	-	9	-	2
Larger size petiole	-	13	-	-
Lower no. cormel	8	2	-	1
Higher no. cormel	-	7	-	-
Mottle leaf blade	3	3		-
Smaller corm size	20	7	2	-
Smaller cormel size	11	6	-	-
Smaller leaf size	10	4	-	-
Decrease acridity	-	3	-	1
Greener leaves	1	3	-	-
Higher disease	6	1	7	6
Lower disease	-		6	7
Improved taste	1	3	-	-
Lower yield	3	4	7	13
Improved yield	-	-	12	5
Many shoots	-	3	-	-
Medium height	-	11	-	-
Shorter height	4	-		2
Smaller petiole size	10	12		
Taller height	5	3	4	
Good taste		-	6	8

HG=Home Garden, - = not reported

Farmers held rich ecological knowledge about taro. Farmers' perceptions of local adaptation and adaptive traits in the study area were similar. It is believed that growing cultivars outside their traditional habitat can have negative effect on their performance. When grown in open fields, the shade-loving taro cultivars may be affected in terms of cormel yield, plant height and petiole quality. Likewise, cultivars grown in home gardens are negatively affected when grown under mono-crop conditions.

4.3.3 Farmers' description of rice ecosystems

Farmers distinguish rice environments by local names which distinguish and / or characterise individual ecosystems. These names are created according to the security of the irrigation water. Farmers characterise them with respect to soil texture, soil colour, and soil fertility. A higher proportion of fertile soils were recorded from the *Tarai* plain than from mid hill. Likewise, lowland soils were more fertile than those from uplands.

In the study areas, farmers broadly divide rice environments into upland and lowland. These lowland fields are further divided into several sub-systems. Table 4.3 shows a comparison of standard rice ecosystems and farmers' classification. The criteria used for classification include a) sources of irrigation water; b) water management system; and c) land management and cultivation practices. In both study areas, farmers describe ecosystems with secure water supply and crop husbandry that correspond to the way scientific literature describes irrigated rice environments. Kaski farmers, however, identify four lowland systems, and Bara farmers identify three others. These reflect the local variation in flooding conditions, water management, and drainage, with farmers adapting cropping systems, cropping intensity, and the use of inputs to those different ecosystems. Variety selection reflects the diversity of rice ecosystems, and farmers identify varieties that are specific to a certain system as well as varieties that can be grown across several systems.

Table 4.3 shows farmers' descriptions of rice ecosystems differ from descriptions in the scientific literature in several ways. The main differences are encountered in the description of non-irrigated lowlands that farmers subdivide according to land, cropping and moisture characteristics. These farm ecosystems, together with upland rice areas, are the main repositories of landrace survival. Hence, the survival of those landraces is dependent on the prevalence of ecosystem diversity. Such associations affect diversity management on-farm.

Table 4.3 Comparison of farmers' and researchers' descriptions of rice environments with respect to characteristic features, Kaski and Bara sites, Nepal.

District	Local name	Farmers' description		Scientific literature (Adopted from IRRI.ORG.2001).	
		Meaning	Land use characteristics[1]	Ecosystems	Description
Kaski	'Ghaiya'	Unbounded sloping or flat lands where a variety of food crops is grown	1. Direct seeded 2. Mixed cropping 3. Weed , rat & bird problems 4. FYM used 5. Only landraces grown	Upland	Rice is direct seeded in non-flooded, well-drained soil on level to steeply sloping fields. Crops suffer from lack of moisture and inadequate nutrition, and current yields are very low.
	'Tari' Mansara	Rain fed bunded and / or unbunded crop land	1. Rice – fallow 2. Drought stress 3. FYM used 4. Mainly landraces	Rainfed lowland	Rice is transplanted or direct seeded in puddled soil on level to slightly sloping, bounded or diked fields with variable depth and duration of flooding, depending on rainfall.
	'Tari' Gurdi	Rained bunded and / or unbunded crop land	1. Rice – fallow/wheat 2. Drought stress 3. FYM used 4. Mainly landraces 5. Improved 'Tari'	As above	As above
	'Sinchit'	Lands with assured irrigation facilities	1. Rice monoculture 2. Rice – wheat /oil crop 3. External inputs used 4. Landraces and modern varieties	Irrigated	Rice is transplanted or direct seeded in puddled soil on levelled, bounded fields with water control, in both dry and wet seasons in the lowlands, in the summer at higher elevations, and during the dry season in flood prone areas.
	Dhav/Sim	Lands with low / no drainage	1. Monoculture 2. Rice – fallow 3. No inputs used 4. Only landraces	Others including, deep water, Dhav	1. Drainage problem 2. Fertile soils 3. Single rice crop grown
Bara	'Ucha'	Fields located at higher level of irrigation canals	1. Monoculture 2. Drought problem 3. Rice-fallow/wheat 4. Use of FYM 5. Improved cultivars	Rainfed Lowland	Rice is transplanted or direct seeded in puddled soil on level to slightly sloping, bounded or diked fields with variable depth and duration of flooding, depending on rainfall.
	Samtal	Similar level to that of irrigation canal	1. Monoculture 2. Up to triple cropping 3. FYM plus chemical s 4. Improved cultivars 5.	Rainfed lowland	
	'Nicha'	Located below level of irrigation canal	1. Monoculture 2. Triple cropping 3. Use of external inputs 4. Improved cultivars	Irrigated	Rice is transplanted or direct seeded in puddle soil on levelled, bounded fields with water control, in both dry and wet seasons in the lowlands, in the summer at higher elevations, and during the dry season in flood prone areas.
	Dhavi / Maan	Swampy lands	1. Direct sown 2. Monoculture 3. Drainage problem 4. No inputs used 5. Only landraces grown	Others including, deep water, Dhav	1. Drainage problem 2. Fertile soils 6. Single rice crop grown

Focus Group Discussion at Kaski and Bara sites, Nepal. Researchers' descriptions adopted from IRRI (1997).

[1] Six criteria used include a) cropping system (mono or mixed crop); b) Rice establishment (direct seeded vs transplanted); c) special problems (weed, drought, excess moisture, soil fertility); d) Post monsoon crop (fallow, double, triple); e) Input use (no inputs, farm yard manure, external inputs); f) Cultivar types (landrace, improved, introduced).

4.3.4 Comparison of soil classification systems

Scientific literature broadly classifies soils based on the extent and proportion of soil nutrients, soil's physical and chemical properties expressed on a standardised scale and as units as described in MCC (2000). On the other hand, farmers classify soils using locally identifiable criteria. In both study areas, farmers classify soils using similar parameters as used by scientists. At the higher level, farmers and researchers describe soils using very similar parameters (Table 4.4). The laboratory analysis of soil samples showed varying degrees of correlation with farmers' classification. The survey revealed that 34 % farmers classified their soils to be fertile. However, the laboratory results show that 11% soil samples contain a high level of nutrients. Above 53% farmers recognised their ecosystems are medium fertile and the laboratory analysis asserted that 42% sample to have medium level of soil fertility. The opposite was true in case of poor soils. Only 12% farmers consider that their soils contain low fertility but the laboratory analysis show >47% samples contain low level of soil nutrients. Farmers and researchers largely agree in recognising soil fertility, especially medium fertility, while the difference was apparent for high or low level of soil fertility. Farmers and researchers largely agree in classifying soils with respect to colour and texture. In most instances, farmers' classifications of soils correspond to the scientific literature.

Table: 4.4 Comparison of farmers' description of soils with soil laboratory analyses. Total farmers (175) versus total soil samples (171) collected from five rice ecosystems of Bara and Kaski, Nepal.

Soil descriptors	Actors		Correspondence	
	Farmers	Researchers	Common	Different
Soil colour strata (no)	8	9	2	15
Good fertility (%)	34	11	11	23
Medium fertility (%)	53	42	42	11
Poor fertility (%)	12	47	12	35
Soil pH (no)	2	3	-	-
Texture strata (no)	6	4	3	7

*Soil fertility classification used for Nepal, BTSM, 1984:

Good: N=>0.15%; OM=>2%; P mg/kg =>25.9-90; K=125.5-225 mg/kg
Medium: N=>0.075%-0.15; OM=1-2%; P=10.5-25mg/kg; K=50.5-125 mg/kg
Poor: N=<0.075%; OM=<1%; P=5-10 mg/kg; K=<50 mg/kg

In conventional system, scientists measure soil quality using standard national or international units while farmers describe their soils with local units. The correlation between farmer fertility and laboratory assessed fertility was poor on individual samples. This low level of agreement was related to the use of different fertility indicators. Researchers determine fertility gradients primarily based on inherent soil nutrients as determined by soil nutrient analysis, while farmers assess fertility mainly based on observable indicators such as productivity assessors including yield, weed growth, soil colour and texture. Farmers argue that crop productivity depends upon whether soil structure and soil moisture are favourable. Even though the soil contains high inherent nutrients, the ecosystem may produce a low yield if soil texture and moisture conditions are not favourable.

Nepalese farmers describe rice environments according to the way water is managed, the rice variety cultivated and the season rice is grown. They are aware on the role adaptation can play in specific as well as non-specific environments. The International Rice Research Institute (IRRI), however, describes rice ecosystems for Nepal primarily based on the availability of irrigation water. Of the total rice area in Nepal, more than 64% is planted with traditional varieties. The area under traditional or improved varieties differs according to the access to irrigation, agriculture inputs, variety options and market opportunity. For example, more than 70% of the rice area of Nepal's *Tarai* is planted with improved varieties (IRRI, 1997, www.irri.org, 2003) where farmers have better access to markets.

Distribution of rice diversity has been found related to the variation of rice growing environments. Farmers' perceptions of soil fertility and ecosystem productivity differed for low level of 'fertility' when compared with laboratory analysis results. The amount of soil nutrients was higher for rain fed soils compared to irrigated ecosystems (Table 10.1). In general, rain fed fields tend to have greater phosphorous and potassium levels than irrigated lowlands, due to lower crop harvest with lower nutrient off takes, less leaching and greater uses of organic manures. The organic material and lower air temperature also affect organic matter and nitrogen levels. Although sandy loams hold less total water than medium and heavy soils, the crop available water often is only slightly less; and the more open structure of a sandier soil allows better root penetration (and root growth).

These inconsistent results are presumably due to differences on the use of criteria used. The farmers' predict soil fertility based on 'actual productivity' in a given management regime while the researchers measure potential based on the availability of the individual soil nutrients. Bellon and Taylor (1993) found that Mexican farmers were consistent when soil fertility compared with laboratory data, organic matter, soil pH, and soil texture. Similar studies carried out in Nepal showed that Nepali farmers classify soils in the same manner as researchers with respect to soil colour and weed abundance (Desbiez *et al.*, 2004). Rana (2004) reports that Bara farmers graded rain fed as low productivity ecosystem, followed by irrigated ecosystems, while deep water/swampy were considered to be fertile. The laboratory analysis, however, largely disagrees with farmers' perception data.

4.4 Discussion and conclusions

The main findings and their implications for on-farm management of crop diversity and knowledge are discussed for taro and rice. The taro farmers have been adapting different practices to suit diverse land uses and environmental factors. Local practices were found to be different for different research sites. *Tarai* farmers primarily cultivate taros on lowland rice fields in deep furrows with the application of external inputs and irrigation. Farmers experience has been that the shape and size of corms are affected by soils type and moisture availability. Such farmers' experiences have been supported by earlier studies (e.g. Ivancic and Levot, 2000). In the mid hills, farmers cultivate taros under upland with organic fertilizers. Mulch is used to suppress weed growth as well as preserve soil moisture. Taro genotypes are therefore chosen that suit local conditions and meet local needs. For example, most mid hill farmers cultivate rich diversity in home gardens but on a small scale. Farmers grew varieties mainly under two cropping systems while six cultivars were grown in one cropping system. This research revealed that the amount of diversity directly relates to the diversity of uses and the persistence of cropping systems.

Farmers select varieties for a particular area on the basis of tuber yield and quality of the taro produce. Cultivars that produce greater yield and those preferred for multiple uses are cultivated under relatively larger areas. This implies that the diversity of ecosystems and diverse local uses encourage farmers to maintain rich diversity. Similarly, diversity of food tradition plays an important role in maintaining taro diversity on-farm.

The review of the literature shows that past research was focused in documenting knowledge related to rice environments, however the scientific bases of this knowledge are poorly addressed. The scientific literature primarily relates to dominant environments and diversity while local knowledge concerns about ecosystems and niches that affect farmers' management of diversity on-farm. Farmers distinguish rice environments with names created after distinctive characteristics. Farmers characterize them against context based descriptors which are also expressed in relative terms. The scientific literature, however distinguishes rice environments using standard descriptors. There was a high degree of agreement between researchers and farmers with respect to environmental characterization. That indicates that local descriptions use similar scientific criteria as researchers to classify soils. The names describe environments better when they are created after the distinctive characteristics.

Farmers' descriptions and subdivision of rice ecosystems differ from those in the scientific literature. Understanding of local knowledge about rice farming systems help increase farmers' decisions process and thereby develop appropriate research methods for the management of rice diversity on-farm. Soil variation is part of the diversity of rice ecosystems and, along with other environmental factors, affects the choice of variety.

Farmers distinguish cropping environments in their own ways no matter which language they speak nor the geographic region they reside. Farmers across continents have also been found to classify soils using common descriptors such as colour, texture, fertility and vegetative indicators as well as water retention capacity and water permeability (Talwar and Rhoads, 1998; Bellon, 1993). Scientists classify soils using slightly different descriptors and descriptive units. In a comparison of scientific and folk soil classification in the mid hills of Nepal (Tamang, 1993) and Zambia (Sikana,1994) found that farmers express soil fertility through the use of phenotypic assessors, whereas researchers elaborate at reduced units. Hence, the degree of correspondence between farmers and researchers may differ, especially at lower levels of description.

Farmers held knowledge about soils and ecosystem factors and their effects on product qualities. Farmers claim that rice becomes tastier when grown on heavier soils with proper application of irrigation water and organic manures. The use of chemical fertilizers, however affects product qualities, especially at heavier doses. Accordingly farmers grow landraces under specific environments and management practices. Despite low grain yield, farmers still cultivate landraces under favorable environments. The varieties with coarse grain and those do not produce an aroma are chosen for marginal environments. Although specific practices and knowledge have enhanced diversity farmers were least aware about potential of local and improved varieties to adapt under varying ecosystems and management practices.

CHAPTER 5: TARO DIVERSITY, USES AND NAMES

In this chapter, research findings related to taro diversity, local uses and adaptive traits are presented. The research presents results about the ways and extent to which taro farmers distinguish diversity. The descriptors used by farmers and researchers are compared to examine the extent of correspondence. Apart from this, farmers' perceptions about variety adaptation are presented with the key findings and their policy implications.

5.1 Introduction

Understanding the existing taro diversity and its distribution on-farm provides is useful for the assessment of whether increasing use values enhance diversity. It is important to understand the relationship between how farmers distinguish varieties using names and the genetic distinctiveness of each unit. Do farmers consistently use the same names within an area or in different areas? Do varieties have similar amounts of genetic diversity within them? The names farmers give to the varieties they manage may be related to the original source and the morphology of the plant. Moreover, these names and traits can be related to agronomic performance, local adaptation and uses. Harlan (1975) discusses how varieties "are recognizable morphologically, farmers have names for them and different varieties are understood to differ in adaptation to soil type, time of seeding, date of maturity, height, nutritive value, use and other properties". Studies in a number of countries have shown that farmers are consistent in distinguishing diversity (Boster, 1985; Bellon and Brush, 1994; Teshome *et al*., 1997; Schneider, 1999; Soleri and Cleveland, 2001; Sadiki *et al.,* 2001). At the same time, studies on durum wheat names in Morocco have shown that the farmers designate broad categories comprising different varieties or entities (Taghouti and Saidi, 2002). In each category, varieties share the same broad name but farmers distinguish them by other traits. Similarly, alfalfa varieties in Morocco are named after their geographic origin. Hence the names of varieties derived from the same eco-site are generic and recall adaptation to local soil and climatic conditions. These two groups differ from each other in growth habit, growth speed after cutting and winter hardiness. In each group, farmers distinguish varieties against agronomic and morphological traits (Bouzeggaren *et al*., 2002). Farmers' bases of distinguishing diversity thus may vary by location, society and culture and also the crop species being studied.

Can 'names' approximate diversity on-farm? Are variety names identifiable units and do they reflect genetically distinct traits? This can have manifold implications on diversity conservation on-farm: i) if farmers are inconsistent then, 'names' do not properly approximate diversity, ii) if farmers are consistent then, 'names' can be used to approximate diversity better, and iii) it helps preserve different varieties if they are always recognized by the same name. Farmers may distinguish diversity using locally created names after distinct traits and sometimes by another local name. This diversity can be measured at different levels. Crop diversity can be measured through agro morphological characterization. Diversity is measured in terms of richness, evenness, and measurements that combine richness and evenness.

It is therefore important to assess the extent to which farmers are consistent in naming taro varieties. Farmers' botanical knowledge may vary between male and female farmers. It is important to understand the level at which male and female farmers consistently distinguish diversity. The names and/or traits farmers use to distinguish their varieties may be consistent; the extent to which these farmer-named units are morphologically distinct is yet unclear.

Understanding the distribution of diversity is the key to understanding which varieties are most likely to be threatened by genetic erosion and what factors actually affect this distribution on-farm. There could be several environmental, social and cultural factors that affect the distribution of crop diversity. Unless these processes and factors are understood, further research would be unable to ensure the potential of this diversity is fully utilized. This chapter presents research findings about i) the extent and distribution of diversity as described by farmers, ii) farmers' description of this diversity, iii) farmers' consistency in naming varieties, and iv) discusses the implications of this knowledge to diversity management on-farm.

5.2 Methods of data collection

Data on farmers' names and descriptors as well as the distribution of diversity were gathered using different research techniques, described individually below.

5.2.1 Participatory Rural Appraisal Survey

The Participatory Rural Appraisal technique was used to locate and assess taro diversity during site selection exercise. A multi-disciplinary team visited 22 villages in Kaski district and recorded the farmer–named varieties at the village level from key informants (Rijal *et al.*, 1998). In this survey, the amount of diversity maintained locally, along with their associated local use and adaptive values, were gathered through informal discussion with key informants of the study villages.

5.2.2 Focus group discussion

Nine each of male and female farmers were invited to observe and identify key farmer's descriptors. A focus group discussion (FGD) was organized after the group observed the diversity block. Farmers were asked to translate the meaning of their names and list descriptors and economically useful traits. With the help of a structured checklist, baseline information and *in situ* characterization work, the extent and distribution of varietal diversity and relative values of all reported taro varieties were studied.

5.2.3 Diversity block

A total of 19 farmers-named varieties were grown in a diversity block. A diversity block is a participatory research technique that allows characterizing varieties under typical farmer management conditions. It has other development objectives as well as to demonstrate local diversity at one spot for public awareness and also to multiply planting materials for exchange among community members (Rijal *et al*., 2000). A total of five plants were planted for each variety. The crops were managed by a local Community Based Organization (CBO) using traditional practices, while the plants were monitored by farmers and scientists to observe and record agro-morphological characteristics. The detailed traits of 19 taro varieties were logged for the above ground parts, underground parts (corm and cormel characteristics), environments and use values.

A total of nine each of male and female farmers were requested to distinguish taro diversity. Farmer descriptors were verified for their consistency, ease of distinguishing traits, reliability of traits, and the frequency of male and female farmers mentioning the traits. Farmers were asked to characterize taro diversity twice, at vegetative stage and after harvest.

The same varieties were grown on-station and characterized against 17 different traits using standard descriptors for taro (IPGRI, 1999). The characterization was performed for both above ground and underground parts. These measurements were compared against those described by farmers.

5.2.4 Diversity fair

Diversity fairs were conducted in 1998, 2000 and 2001 to encourage farmers to assess genetic diversity and promote farmers' choices for different crop varieties. The inventory was prepared on the basis of varieties displayed by farmer groups in the first diversity fair of 1998. These varieties were grown together to reduce duplication of accessions and also multiply planting materials for experimental purposes.

5.2.5 Baseline survey

The farming household was used as the basic sampling unit for the study. Households were categorized according to their wealth category by doing a well being exercise. In order to identify which HHs to interview, the study used proportionate stratified sampling design. In Kaski, 206 sample households (22% of total HH) were surveyed for baseline studies. A detailed methodology adapted for baseline survey is described elsewhere (Rana *et al.,* 2000).

5.2.6 Data analysis

The descriptive and qualitative data are presented in two-way tables. The quantitative data related to names and descriptors are compared using descriptive statistics. Similarly, diversity is measured by the Simpson Diversity Index and different diversity indices have been used. The agro morphological data were analyzed using descriptive statistics.

The extent and distribution of taro diversity is assessed using four squared methods created based on the area covered by individual varieties and the number of households growing particular varieties.

Local varieties were categorized into groups that occupied large or small areas (based on average area), and those varieties that were grown by many or few households (based on number of households). This Four Cell Analysis (FCA) method can be used in a variety of ways. Rana (2004) calculated a “mean area in hectares per household” for each variety grown in a village to decide whether a variety should be considered as grown in a large or small area at the household level. In this research, taro varieties are grouped into four cells according to their area coverage (large or small) and the number of households growing taro (many or small).

	Large area	Small area
Many farmers		
Few farmers		

5.2.7 Consistency and correspondence analysis

The descriptors and descriptive units were studied separately with equal number of male and female farmers of the same area. The degree of consistency between male and female farmers is compared.

Farmers’ descriptors were compared with measured data to see the degree to which they correspond to agro morphological measurement. For this purpose those names are taken which farmers have created based on their distinct characteristics.

5.3 Results

5.3.1 Distribution of taro diversity at the household level

Table 5.1 presents socio-economic characteristics of households, total number of taro varieties grown, area under taro and productivity of individual varieties. The highest number of varieties was recorded at Kaski (24) followed by Bara (3) and the lowest at Jumla (1).

About 70% of HH sampled in Kaski cultivate taro in home gardens or in larger *Bari* land ecosystems. The maximum number of varieties maintained by a household was eight but there was only one such case recorded. On average, Kaski farmers maintained 0.13-2.33 varieties per household (mean value 1.524).

Taro diversity per HH was positively ($p<0.05$) related to wealth category as well as number of parcels of *Bari* land (Rana *et al.,* 2000). The wealthier households grow more taro varieties than those poorer households. "Hattipow", "Khari pindalu" and "Lahure karkalo" were the most widely grown varieties by all categories of farmers. Of the 24 varieties, nine were grown by at least 5 households. However, >15 varieties were maintained only by a few households (Table 5.1).

Table: 5.1 Household characteristics of taro growers in Jumla, Kaski and Bara sites, Nepal, 1999.

SN	Parameters	Unit	Jumla, High hill	Kaski, Mid hill	Bara, *Tarai* plain
1	Total number of households	Number	759	941	914
2	Sampled households	Number	180	206	202
3	Average family size	Persons/HH	6.0 ± 0.2	6.5 ± 0.2	6.5 ± 0.2
4	Average food sufficiency months	No. of months	7.5 ± 0.3	8.3 ± 0.3	7.4 ± 0.3
5	Cultivable farm size *khet*+*bari*+*lekh*)#	Hectare	0.33 (179)	0.65 (195)**	0.74 ± 0.1 (187)
6	Land fragmentation of cultivable farm	No. of parcels	18.9 ± 0.9	5.2 ± 0.3	4.0 ± 0.2
7	Average area under taro	m^2/HH	na	94.5 ± 7.2 (96)	na
8	Varieties recorded	Number	1	24	3
9	Number of varieties	Number/HH	≤1	2.33 ± -0.13 (146)*	≤1
	Seed quantity used	kg/HH	na	18.7 ± 1.7 (61)	na
10	Productivity of varieties	kg/m^2	na	0.3 -16.7	na

Source Baseline survey, LI-BIRD, Pokhara, Nepal
*Figure in parentheses indicates number of responding households.
na = not available; taro cultivated in home gardens as intercropped with other varieties and crop species. Only 96 households responded area planted.
# *Khet* is bunded and irrigated or rain fed land, *Bari* is unbunded and unirrigated upland.
HH: Household

5.3.2 Taro diversity revealed by different studies

In the past, several studies have employed different methods to assess the extent and distribution of taro diversity on-farm. Table 5.2 presents the lists of farmer–named varieties recorded through various methods from the study area. Interestingly, all varieties farmers have been maintaining are recognized by their names. The amount of varietal diversity varied with the method of data collection. PRA tends to underestimate the real diversity while the diversity fair often over estimated this number because of the competitive nature of the activity where farmers tend to increase diversity. However, it may be that diversity fair is able to capture diversity at household level. The evenness or dominance of diversity was estimated by Simpson Index (SI: 0.506, SE ± 0.0022, CV:1.33).

Table 5.2 Inventory of taro varieties recorded under different studies in Kaski, Nepal, 1998-2000

PRA survey 1998	Baseline survey 1999	Diversity fair 1998	Diversity fair 2001
1. Dudhe karkalo	1. Chhaure	1. Bhaisekhutte pindalu	1. Assame kalo
2. *Hattipow*	2. Dado ratomukhe	2. Burmeli pindalu	2. Bhaisekhutte
3. Kalo karkalo	3. Dalle	3. Chhatre pindalu	3. Burmeli pindalu
4. Khari	4. Dudhe Karkalo	4. Chhoto khari pindalu	4. Chhatre pindalu
5. Khujure	5. *Hattipow* pidalu	5. Dalle pindalu	5. Dalle pindalu
6. Lahure karkalo	6. Juke	6. Danthe karkalo	6. Dalle rato
7. Panchmukhe	7. Kalo karkalo	7. Dudhe Karkalo	7. Dudhe Karkalo
8. Ratomukhe	8. Kalo pindalu	8. Dudhe seto pindalu	8. Dalle khari
	9. Khari pidalu	9. Gante pindalu	9. *Hattipow* pidalu
	10. Khujure rato pindalu	10. *Hattipow* pidalu	10. Jaluka
	11. Khujure seto	11. Jaluka	11. Jante pindalu
	12. Lahure karkalo	12. Jante pindalu	12. Juke pindalu
	Rato	13. Juke pindalu	13. Kalo lahure
	14. Rato khari	14. Kalo karkalo	14. Kalo khujure
	15. Rato lamo	15. Kalo khujure	15. Kalo pindalu
	16. Rato panchmukhe pindalu	16. Kalo pindalu	16. Kalo dudhe
	17. Rato pindalu	17. Kat pindalu	17. Kaat pindalu
	18. Ratomukhe pindalu	18. Khari pidalu	18. Kasre
	19. Satmukhe	19. Khujure	19. Khari pidalu
	20. Seto karkalo	20. Khujure rato pindalu	20. Khairo *Hattipow*
	21. Seto lahure	21. Lahure karkalo	21. Khujure
	22. Seto pindalu	22. Lahure pindalu	22. Khujure seto
	23. Thado	23. Lamo khari	23. Khujure sano
		24. Lamo thado pindalu	24. Khujure rato
		25. Mane pindalu	25. Lahure seto
		26. Panchmukhe *Hattipow*	26. Mane pindalu
		27. Panchmukhe seto	27. Panchmukhe
		28. Rato chhaure	28. Thagne
		29. Rato dudhe	29. Panchmukhe seto
		30. Rato karkalo	30. Rato khari
		31. Rato panchmukhe pindalu	31. Rato *Hattipow*
		32. Rato pindalu	32. Rato panchmukhe
		33. Ratomukhe pindalu	33. Rato pindalu
		34. Seto karkalo	34. Ratomukhe pindalu
		35. Thulo kalo pindalu	35. Seto pindalu
			36. Seto kari
			37. Satmukhe *Hattipow*
			38. Tarule pindalu
			39. Naumukhe
			40. Jhamte pindalu
			41. Jare
			42. Thado pindalu

Source: LI-BIRD, Pokhara, Nepal

5.3.3 Area coverage of individual varieties

Traditionally taro is grown in open fields and in home gardens. The exact taro area has been difficult to estimate when it is intercropped with maize or grown in small patches in backyards or inside forest in slash - and - burn agriculture. The households could estimate area for individual varieties if they are grown at larger (measurable) scales. Table 5.3 shows some varieties are grown widely by many households but others in small areas and by only a few households.

There are only four varieties that are widely grown on relatively larger scales while four others are grown in larger areas but by very few households. A total of five other varieties are grown by many households but in small areas. More importantly, the majority of the varieties (15) grown in small areas are maintained by a very few households. The most widely grown varieties include “Hattipow”, “Khari pidalu”, “Khujure rato” and “Rato pindalu” whereas “Dudhe Karkalo”, “Kalo karkalo”, “Lahure karkalo”, “Rato mukhe” and “Rato panchmukhe” were common, though they were grown on small scales. Except “Rato mukhe pindalu” and “Rato panchmukhe”, the remaining varieties were *Xanthosoma* taro, adapted to shady conditions such as home gardens. A few plants are grown for varieties that prepare special recipes from the petiole. In many ways four varieties “Chhaure”, “Danthe pindalu”, “Kalo pindalu” and “Seto pindalu” are similar.

Table 5.3: The number of farmer – named taro variety by the relative area coverage and frequency of farmers growing varieties in Kaski, Nepal

Characterization of varieties by farmer perception in focus group discussion	Household growing taro varieties (no) ?	Farmers growing taro varieties (%)Δ	Popularity Index*	Tuber yield g/plant**
Large area by many households				
1. *Hatti pau pidalu*	81	55.5	18.7	370
2. *Khari pidalu*	65	44.5	-	443
3. *Khujure rato*	39	26.7	55.7	400
4. *Rato pindalu*	14	9.6	-	-
Large area by few households				-
1. *Chhaure*	1	0.7	50.2	-
2. *Danthe pindalu*	NR	NR	-	-
3. *Kalo pindalu*	2	1.4	-	-
4. *Seto pindalu*	1	0.7	-	284
Small area (few plants) by many households				
1. *Dudhe karkalo*	19	13.0	-	227
2. *Kalo karkalo*	33	22.6	7.5	196
3. *Lahure karkalo*	38	26.0	21.9	-
4. *Rato mukhe pindalu*	14	9.6	30.6	-
5. *Rato panchmukhe pindalu*	16	11.0	18.4	343
Small area (few plants) by few households				
1. *Chhatre*	2	1.4	28.8	-
2. *Gante*	3	2.0	8.3	-
3. *Kaat*	NR	NR	30.6	-
4. *Khujure Kalo*	NR	NR	41.8	-
5. *Khujure seto*	1	0.7	41.8	-
6. *Rato*	1	0.7	30.6	-
7. *Rato danthe*	NR	NR	27.1	-
8. *Rato khari*	1	0.7	-	-
9. *Rato lamo*	1	0.7	-	-
10. *Satmukhe*	1	0.7	-	-
11. *Seto karekalo*	1	0.7	-	-
12. *Seto lahure*	1	0.7	-	-
13. *Thado*	1	0.7	30.61	-
14. *Thado ratomukhe*	2	1.4	-	-
15. *Thayoune/Thagne*	NR	NR	5.1	-

? Baseline data (n=206; 146 taro growers, 1999); NR=Not reported in baseline survey but mentioned in the FGD.
Δ % figure does not add up to 100% as the same household grew more than one variety.
*Weighted mean value calculated as the number of response × score (1- 4) / total number of respondent (N): the higher the score higher the use values. Data adapted from Table 6.4.
- not available
** Yield data recorded from a field trial in Kaski (Chapter 8)

Table 5.3 shows that farmers' adoption is related to variety performance and / or their local uses. The popularity index indicates farmers' assessment of varieties against food preferences. The higher index values indicate wide uses and vice versa. Despite lower popularity index, the variety "Hattipow" was found to be widely grown by many households. Conversely, the variety "Khujure" that had the highest popularity index and also produced the highest tuber yield per plant was cultivated by fewer households than “Hattipow”. The variety “Panchamukhe” which has greater popularity index along with good tuber yield was still grown by a small number of households. Despite low popularity index most varieties of *Xanthosoma* spp were grown by significant number of households for specific uses. Surprisingly, “Chhaure”, the second most popular variety was grown only by one household. Despite several criteria listed, some farmers were maintaining individual varieties for single preferred characteristic. The maintenance of taro diversity on-farm is therefore dependent on; i) potential tuber yield, ii) wide food value, and iii) specific food values. Apart from high yield and high popularity index, some varieties were grown by fewer households than those known for special uses. Varieties with special uses are grown on a scale of few plants only by households who are familiar with such specific dishes. The varieties grown for high yield or multiple uses are grown at larger scales. Farmers determine the area allocated for popular and distinct varieties with due consideration of varieties that can substitute and those with distinct values. Hence, farmers make categorical selection according to their specific or general use values. Farmers’ hesitation of wider adoption of varieties that have high popularity index, including tuber production is a point of discussion. As the research results show ecological benefits are important for farmers (Chapter 4). Farmers cultivate diversity for their own uses. However, farmers have been constrained because of the unavailability of specific environment required by some varieties. At the same time farmers have been maintaining less preferred varieties for their better adaptation to local condition. Although taro grows under varied soil types most high yielding varieties are cultivated under heavier soils. The varieties Hattipow’, ‘Khari’, ‘Panchamukhe’ and ‘Lahure’ are preferably grown under such soils (Chapter 3, Table 3.2). Direct observations reveal that farmers cultivating heavier soils grow taros widely than with light textured soils. Some varieties are specifically preferred for intercropped systems such as *Xanthosoma* species. Past studies comparing performance of such varieties under varied environments and cultivation practices are inadequate.

5.3.4 Farmers' perceptions about variety adaptation

Table 5.4 shows that the maintenance of taro diversity is linked with environment factors including temperature, moisture and sunlight. It is evident that farmers have identified varieties suitable for different crop ecosystems. Except for some varieties that grow widely across different cropping system, most varieties are cultivated under specified cropping ecosystem. Because of a very shade-loving nature, varieties belonging to *Xanthosoma* spp are always grown under home garden or agro-forestry. Farmers determine diversity through direct selection of varieties for specific cropping system, soil types and soil fertility. The varieties that produce corms are cultivated as mono crop whereas varieties that produce cormels are intercropped with other crop species. Similarly, varieties that produce corms are preferably grown under more fertile soils while varieties that produce cormel grown under relatively marginal environments (Table 5.4).

Farmers have identified varieties suitable for different temperature, soil fertility, moisture regimes and solar radiation and thus enhanced diversity. *Tarai* farmers cultivate varieties that produce corms while the high hill farmers have been growing varieties that produce cormel. In mid hill, farmers have been growing different varieties that produce corms, cormels and the corms as well as cormels. In both the mid hill and on the *Tarai* areas farmers have been maintaining wild taro under natural conditions. Despite their special food value, farmers have not tried them under farm lands. Thus variable agro ecosystems, niches and diverse production systems demand genetic diversity to adapt the specific situations. Diversity of such conditions in Kaski village, covering wetlands to uplands, varying soil types and their land capability, altitude ranges etc, played determining roles in conservation of a large amount of taro diversity.

Table: 5.4 Description of taro diversity according to adaptive value across agro ecological zones, Nepal.

Varieties	Altitude (m)	Agro-ecological zones	Specific adaptation/habitats
Bermeli pindalu	670-1200	Middle hill	Adapted to fertile soils near to compost pit; shade loving, as sole crop
Bhaishikhutte pindalu	1200	Middle hill	Adapted to open and un-shaded upland fields; Grows well in fertile soil as inter or sole crop
Chhatre/juke	900-1200	Middle hill	Adapted to inter cropping; *swara bari land*
Chhaure	670-1200	Middle hill	Adapted to inter cropping; *swara bari land*
Dudhe Karkalo	670-1200	Middle hill	Adapted to fertile soils near to compost pit ; shade loving, few plants; perennial; as sole crop
Gante	1200	Middle hill	Adapted to inter /sole cropping; *swara bari land;* annual planting
Hatti pau pidalu	670-1200	Middle hill	Adapted to open fields;grows well in black and fertile soil; grows in both inter or sole crops; annual planting
Jaluka	670-1200	Middle hill	Adapted to aquatic condition; wild forms along stream
Kaat	850	Middle hill	Adapted to inter cropping; *swara bari land*
Kalo karkalo	670-1200	Middle hill	Adapted to fertile soils near to compost pit ; shade loving, few plants; perennial; as sole crop
Kalo pindalu	800-1200	Middle hill	
Khari pidalu	670-1200	Middle hill	Adapted to open south facing fertile land; maize can be planted in low density
Khujure Kalo	850-1200	Middle hill	Adapted to south facing slope Inter cropping with ginger, yam, sweet potatoes, pigeon pea, beans and sesame
Khujure rato	670-1200	Middle hill	Adapted to south facing slope Inter cropping with ginger, yam, sweet potatoes, pigeon pea, beans and sesame; water draining field
Khujure seto	670-1200	Middle hill	Adapted to fertile soils Often inter or mono cropping
Lahure karkalo	670-1200	Middle hill	Adapted to fertile plots near homestead; shade loving, sole crop
Papado pindalu	2200-2300	High hill	Adapted to cold temperature
Rato dhanthe	800-1000	Middle hill	
Rato Khari	670-1000	Middle hill	Adapted to open *bari*, less fertile soil
Rato mukhe pindalu	800-1200	Middle hill	Adapted to upland, inter cropping
Rato or Raate	670-1200	Middle hill	Adapted to upland, inter cropping
Rato panchmukhe pindalu	670-1200	Middle hill	Adapted to upland, open fields, grows well in fertile soil; grows as mixed or sole crop
Rato pindalu	80-90	*Tarai*	Adapted to *khet* land conditions
Satmukhe	600-1400	Middle hill	Adapted to upland sandy soil, Grown as inter or sole crops
Seto pindalu	90-100	Terai	Adapted to upland (ridged) conditions in *Tarai*
Thado	900-1200	Middle hill	Adapted to upland *bari* Often inter cropped
Thado ratomukhe	600-1400	Middle hill	
Thagne	670-1200	Middle hill	Adapted to upland *bari*; Inter cropping with ginger, yam, sweet potatoes, pigeon pea, beans and sesame

As demonstrated in Table 5.5 farmers have identified varieties for different i) climatic conditions including cold and hot climate, ii) moisture regimes including rain fed, low land or swamps, iii) solar radiation as in mono and inter cropping, iv) fertility regimes such as medium and poor, and iv) crop management practices including home gardens. Despite increasing documentation of farmers' ecological knowledge past studies are inadequate that elaborate the interactions between environment factors and taro diversity.

Table 5.5 Abiotic factors influencing the extent and distribution of taro diversity in three contrasting production systems of Nepal.

Abiotic factor	Type of adaptation	Specific examples of taro Varieties
Temperature	Chilling tolerance Heat tolerance	*Papado pindalu* adapted at 2300 m in Jumla, high mountain ecosystem *Seto pindalu* adapted in upland land, and *Rato pindalu* in *Khet* land at 80m in Terai tropical conditions
Water regime	Rain fed upland Aquatic	Many *Jaluka* (wild) grown along the streams
Solar radiation	Shade tolerance Adapted to inter cropping Adapted to open south facing fields	*Dudhe Karkalo, Kalo karkalo, Burmeli, Lahure karkalo* grown perennially in home gardens under the shades *Khujure kalo, khujure rato, Thagne, Hattiapu, Ratomukhe, Rato* *Bhainsikhutte, Hattipow, Khari, Khujure kalo and rato, Rato khari*
Soil fertility	High fertility Low fertility	*Dudhe karkaklo, Bermeli, Lahure, Kalo karkalo* adapted to near compost pits; *Hattipau, Khujure seto, Rato panchmukhe* grown in black (high humus) fertile soil for large size corm *Rato khari, Satmukhe* in upland sandy soil
Farmer management	*Swara bari land* [1] South facing open *bari land* Khoriya fields[2] Sole cropping Intercropping Homegardens *Khetland*[3] Compost pit[4]	*Chhatre, Chhaure, Gante, Kaat* *Khujure kalo, khujure seto, Khari, Hattipau pindalu* *Panchmukhe, Khujure, Khari* *Bermeli, Dudhe karkalo, Kalo karkalo* *Thado, Thagne, Rato, Ratomukhe, Khujure rato, Khujure seto, Kaat, Hattipau, chhaure, chhatre, Bhainsikhute* *Bermeli, Dudhe karkalo, Kalo karkalo* *Rato pindalu* (Bara*) and Jaluka* in Kaski *Bermeli, Dudhe karkalo, Kalo karkalo, Lahure karkalo*

1 large size upland rainfed terraces in the hills where maize/millet or upland rice are predominat cropping systems;

2 swidden fields, private forest lands are slashed and burnt in winter and taro crops are grown mixing with ginger, yam, beans, sweet potatoes, sesame and pigeon pea.

3 paddy fields

4 near homestead kitchen waste or compost pit where fertility and water regime is high

5.3.5 Farmers' distinguish diversity using local names

Table 5.6 summarizes the list of farmers-named varieties, botanical descriptions, the literal meaning and traits used to distinguish this diversity. The results show that Kaski farmers distinguish diversity by names created for individual populations locally. At a higher level, diversity is distinguished at botanical class and the diversity within each botanical class. The term 'Pidalu' for example refers to *Colcocasia* spp whereas 'Karkalo' indicates varieties belonging to *Xanthosoma* spp. Farmers name varieties using two levels of descriptors, especially when first name inadequately distinguishes it from other varieties. This applies in naming varieties for both botanical classes. At the lower level, farmers distinguish diversity by names created against traits attached to individual varieties. The basis can be the colour of the petiole, plant sap or cormel, or the size of the corm or cormel they produce. If there are two names attached to one variety then, farmers recognize 'Karkalo' as a secondary name, which is appended to the primary name. Similarly, 'Pidalu' as a secondary name is attached to *Colocasia* spp if the first name does not distinguish it from other similar named varieties. "Hattiow" (elephant feet) and "Bhaisikhutte" (buffalo feet) are named according to their corm characteristics. They are named because the corms exactly resemble the shape and size of elephant or buffalo footprints. Other farmers name varieties according to the presence of buds on their corms; "Panchamukhe" and "Satmukhe" are examples of this. Varieties are named according to the number of cormels they produce. Names like "Khujure" and "Chhaure" describe their distinctive characteristics. The varieties that produce cylindrical corms are called "Khari", which can have sub-names if some produce short sized corms. Farmers also distinguish diversity by names created according to their habitat. *Jaluka* refers the varieties that grow in a semi-aquatic environment.

Farmers distinguish diversity using categorical descriptors applicable to individual varieties. Farmers distinguish taro diversity using distinctive morphological traits which are measured by locally defined units. Farmers use different descriptors for varieties according to their botanical group. Varieties that produce corms are distinguished according to their shape, size and color. Varieties of *C antiquorum* are distinguished by counting number of cormels and skin colour. At the same time varieties are described by petiole colour. ‘Kalo karkalo’ and ‘Dudhe karkalo’ are examples.

Table :5.6 Description of farmers – named varieties of taro, Kaski, Begnas, *In situ* characterization (2000) (Source: Focus Group Discussion (2001).

Local name	**Botanical name**	**Literal meaning of farmers' descriptors***	**Distinguishing morphological characteristics***
Bhaishi khutte	*C. esculenta var. esculenta*	Multiple croms like buffalo-foot prints, annual, unbranched crom; many buds few cormels; Cup-shaped leaf; morphotype similar to Hattipow, Panchmukhe seto, Panchmukhe.	Flat and multi-corm types, slow and late leaf senescence, white bud color.
Burmeli	?	Iintroduced from Burma; white leaf, stem and petiole color; long cormel; stem releases white colored sap when squeezed; adapted to home gardens.	V shaped leaf separated at petiole junction, discontinued leaf margin.
Chhattre	*C. esculenta var. antiquorum*	Leaf shaped like umbrella; long and green leaf color; red bud with round corm.	Dumb-bell corms with pink bud, pink skin and with conical cormels.
Chhaure	*C. esculenta*	Puppies; multi-cormel types like puppies.	Long cormels with red bud; round corm.
Dhudhe karkalo	*C. esculenta*	Milky white petiole, bud & sap color and thick plant; no corm but profuse root system; round shaped leaf; adapted to home gardens	Multi-corm type, no cormel, cylindrical corm and cup shaped leaf.
Gante	*C. esculenta*	Short; petiole black, branching corm and large sized cormel; red bud, petiole and sheath color; round shaped small corm.	Dumb-bell shaped corm with round corms.
Hattipow	*C.esculenta var. esculenta*	Corm shaped like elephant foot; tall and thick plants, whitish and broad leaves; large multi-corms with depressed bud; light green petiole; rough (*Jerro*) leaf; few cormels; adapted to open field.	Flat and multi-type corm, slow and late leaf senescence with white bud.
Kaat	*C . esculenta var. esculenta*	Easy cooking in Gurung dialect; soft and round leaf shape, excellent cooking quality, similar to Rato panchmukhe.	Buds red color; many buds.
Kalo karkalo		Black leafy taro; perennial, purple pigmented, branching corm and cormel; long cormel with pink bud color; profuse root system; black petiole and purple mid ribs; full cut tapered leaf; adapted to home gardens.	Pigmented corm and cormels with red bud.
Khari chhoto	*C. esculenta*	Short corm; pink petiole; long corm size, simliar to Thagne khari, Thangne, Khari pindalu.	Corm grown upright; taro covered by feathery sheath.
Khari pindalu	*C. esculenta*	Literally means cylindrical corm.	
Khujure	*C. esculenta var. antiquorum*	Multi-cormels; with many small cormels; itchy corms; many cormels with white buds, white petiole; dark purple petiole junction; purple leaf margin; round leaf.	Round corm and cormels with white buds; corm are acrid.
Khujure kalo	*C. esculenta var. antiquorum*	Black colored multi-cormels; petiole black, corm and cormels both edible, non itching; white bud; many cormels; petiole purple (kalo); long leaf.	Branching corm round in shape with white bud.
Khujure seto	*C.esculenta var. antiquorum*	White colored multi-cormels; petiole black, corm and cormels itching; any cormels, plenty of black petiole, purple leaf margin.	Branching, corm and cormels round and very small with white bud.
Lahure karkalo	*Xanthosoma sagitifolia*	Exotic leafy taro; cormel shape looks like young mouse; adapted to home gardens.	Tall plant; long cormel profuse root system; leaf bifurcated; soft skin.
Lahure pindalu	*Xanthosoma sagitifolia*	Exotic leafy taro; perennial, robust plant, adapted to home gardens.	Oblong corm and cormels purple pigmented petiole margin with pink bud.
Panchamukhe	*C.esculenta var. esculenta*	Five-faced corm; tall and thick plants, whitish and broad leaves; looks like Hattipow many buds with depressed buds; large corm size; rough leaf (jarro) with tall plant; thick vein.	Flat and multi-corm type; without cormels; white bud and slow and late senescence.
Panchmukhe seto	*C . esculenta var. esculenta*	Five-faced white corm; tall and thick plants, whitish and broad leaves; multi-corm types with white bud color; light green petiole; similar to Panchmukhe, Bhainsikhutte, Hattipow.	Clustered corm without cormels and white bud and slow and late senescence.
Rato or Raate	*C.esculenta var. antiquorum*	Red; purple petiole color.	Red seminal roots with white buds, curbed peduncle at petiole junction.
Rato mukhe	*C.esculenta var. antiquorum*	Red colored corm; red bud color with large and round corm/cormels	base of petiole color pink; leaf peduncle curbed, thick leaf blade; red roots.
Rato thado	*C. esculenta var. antiquorum*	Red corm grown upright; white buds; tall plant.	Purple point at dorsal side of petiole junction, upright growth of corm.
Satmukhe	*C. esculenta var. esculenta*	Seven-faced corm; morphotypes similar to Khari chhoto, Thado mukhe, Thagne.	Multi-corm type covered by feather like stuff (*bhutla*).
Thado	*C. esculenta var. esculenta*	Upright growth of the corm.	Cylindrical corm, non branching.
Thagne Khari	*C. esculenta var.*	Old clothes; feather like tissues covering the corms (thagne).	Purple point at petiole junction, large cormels.

5.3.6 Assessment of farmers' consistency in naming varieties

It is important to identify the key custodians of diversity to know whether diversity management is related to specific preferences. These names could be reliably used when created by the more knowledgeable custodians. Table 5.7 shows the different ways male and female farmers distinguish diversity on-farm. The results show that post-harvest descriptions are more effective than on the standing crop. Regardless of gender, the underground parts were easier to distinguish than the above-ground parts. Farmers referred "Karkalo" or "Pindalu' as key descriptor to make distinction between them. The result shows that female farmers consistently distinguish diversity based on characteristics of the above-ground parts whereas male farmers are consistent in distinguishing diversity from the underground-parts such as corm shape.

Female farmers expressed that their male counterparts were more interested in managing crops grown on a large scale. On the other hand, female farmers are more interested in diversity that enhances benefits in terms of adaptation, yield and nutrition. The participant farmers univocally argued that we hold more knowledge about diversity when i) we are interested in particular aspects, and ii) get involved heavily in managing diversity'. This research concludes that farmers directly involved in maintaining diversity held both ecological and botanical knowledge associated with their crops (Table 5.8).

This research results would have strategic implications for future research, development and on-farm conservation. Effective management of crop diversity on-farm can be achieved only when the conservation projects involve female and male farmers, so as to integrate their associated knowledge into action.

Table: 5.7 Male (M) and Female (F) farmers' descriptors of taro, Kaski.

Cultivars	Bhaisikhutte		Chhatre		Chhaure		Dudhe karkalo		Gante		Hattipow		Kalokarkalo		Kaat		Khujure		Khujure kalo		Khujure seto		Lahure pidalu		Panchamukhe		Panchamukhe seto		Raate		Rato mukhe		Thado mukhe		Thangne khari		Total
Gender/Trait	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
Short height	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5	0	0	0	0	0	0	0	0	0	0	8
Tall plant	0	0	0	0	0	0	0	0	5	5	4	7	0	0	0	0	0	0	4	6	7	7	0	0	0	0	0	0	5	8	0	0	5	10	4	4	81
Round leaf	0	0	0	0	0	0	7	9	4	5	1	4	0	0	6	8	0	0	0	0	0	0	0	0	0	0	6	5	0	0	0	0	0	0	0	0	55
Thick leaf	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	7	0	0	0	0	10
Tapered leaf	0	0	0	0	0	0	0	0	0	0	0	0	2	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
Waxy leaf	0	0	0	0	0	0	6	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	7	0	0	25
Full cut leaf	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Large leaf	5	5	8	9	6	9	0	0	0	0	0	0	0	0	0	0	0	0	9	6	0	0	0	0	0	0	0	0	6	5	6	7	0	0	5	10	96
Few petioles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	5	0	0	0	0	0	0	0	0	0	0	9
Many petioles	7	7	0	0	0	0	0	0	0	0	0	0	0	0	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	4	7	6	0	0	56
L/ green petiole	8	9	5	7	5	9	0	0	0	0	5	9	0	0	0	0	0	0	0	0	4	6	0	0	6	6	5	8	0	0	0	0	0	0	4	5	101
Purple petiole	0	0	0	0	0	0	0	0	5	9	0	0	9	9	5	8	4	7	6	9	4	8	0	0	0	0	0	0	7	9	0	0	0	0	0	0	99
Small petiole size	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Depressed bud	0	0	0	0	0	0	0	0	0	0	10	8	0	0	0	0	0	0	0	0	0	0	0	0	6	12	0	0	0	0	0	0	0	0	0	0	36
White bud color	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	2	10	8	3	0	0	0	0	0	0	4	10	5	8	0	0	6	19	5	12	97
Many buds	9	12	0	0	0	0	0	0	0	0	8	13	0	0	5	8	0	0	0	0	0	0	0	0	11	14	9	8	0	0	0	0	0	0	0	0	97
Pink bud	0	0	10	14	0	10	0	0	0	12	0	0	2	8	10	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	14	0	0	0	0	104
Few cormel	5	10	0	0	0	0	0	0	0	0	6	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6	0	0	38
Long cormel	0	0	0	0	0	0	0	0	0	0	0	0	2	12	0	0	0	0	0	0	0	0	14	11	0	0	0	0	0	0	5	6	0	0	7	15	72
Many cormels	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	15	8	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43
Large corm	5	8	0	0	0	0	0	0	0	0	6	9	0	0	0	0	0	0	0	0	0	0	0	0	6	8	0	0	0	0	0	0	0	0	0	0	42
Round corm	0	0	11	8	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	6	0	0	4	9	52
Small corm	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Upright corm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8	0	0	16
Profused roots	0	0	0	0	0	0	2	5	0	0	0	0	7	4	0	0	0	0	0	0	0	0	8	7	0	0	0	0	0	0	0	0	0	0	0	0	33
Total descriptor	6	6	4	3	3	4	4	4	4	5	7	7	6	5	5	5	4	4	5	5	3	3	2	2	6	6	4	4	4	4	6	6	6	6	6	6	
Score	**39**	**51**	**34**	**38**	**17**	**32**	**18**	**24**	**18**	**35**	**40**	**59**	**27**	**47**	**34**	**46**	**21**	**37**	**35**	**34**	**15**	**21**	**22**	**18**	**36**	**50**	**24**	**31**	**23**	**30**	**37**	**44**	**32**	**56**	**29**	**55**	

Farmers' characterization at vegetative stage (9 male and 9 female) on site and post harvest samples (12 male and 12 female farmers), Begnas

Table: 5.8 Female and male farmers' descriptors in distinguishing taro diversity, Kaski, Nepal.

Farmers' Descriptor	Farmers' given Values	Total score	Score by gender		Per cent by gender	
			Male	Female	Male	Female
Plant height	Short height	8	3	5	37.5	62.5
	Tall plant	81	34	47	42.0	58.0
Leaf	Round leaf	55	24	31	43.6	56.4
	Thick leaf	10	3	7	30.0	70.0
	Tapered leaf	11	2	9	18.2	81.8
	Waxy leaf	25	10	15	40.0	60.0
	Full cut leaf	10	5	5	50.0	50.0
	Large leaf	96	45	51	46.9	53.1
Petiole	Few petioles	9	4	5	44.4	55.6
	Many petioles	56	31	25	55.4	44.6
	L/ green petiole	101	42	59	41.6	58.4
	Purple petiole	99	40	59	40.4	59.6
	Small petiole size	10	5	5	50.0	50.0
Bud/face	Depressed bud	36	16	20	44.4	55.6
	White bud color	97	33	64	34.0	66.0
	Many buds	97	42	55	43.3	56.7
	Pink bud	104	32	72	30.8	69.2
Cormel	Few cormel	38	13	25	34.2	65.8
	Long cormel	72	28	44	38.9	61.1
	Many cormels	43	18	25	41.9	58.1
Corm	Large corm	42	17	25	40.5	59.5
	Round corm	52	25	27	48.1	51.9
	Small corm	8	4	4	50.0	50.0
	Upright corm	16	8	8	50.0	50.0
Root	Profuse roots	33	17	16	51.5	48.5

Female farmers are better than male farmers at noting almost every trait (Table 5.7). However, male farmers were better to identify traits related to corm on which they are most interested. This information provides useful basis to work with right actors in future research, development and conservation activities.

5.3.7 Agro morphological characterization

Table 5.9 presents results of post-harvest measurements of qualitative traits related to petiole, corms, cormels and buds. These parts were measured with respect to color, shape and size and the petiole sheath characteristics. The varieties were characterized with respect to colour of plant parts, shape and size of corms or cormel and the corm manifestation. Results showed that variation exists among the varieties.

Table 5.10 presents the measurement taken on varieties with respect to plant height, leaf length and leaf width number of cormels and corm and cormel yield. With respect to plant height varieties were found to be different; variation was minimal for their leaf width and leaf length. The tested varieties greatly differed in terms of the number of cormels they produce. The yield parameter was found to be very variable. For one and other traits farmers named varieties found to be diverse. Table 5.11 presents the researchers' assessment of agro-morphological measurements and their correlation matrices. The following section compares botanical knowledge of male and female farmers with measured data recorded on-site.

5.3.8 Farmers consistency in naming diversity

The plants may express differently when grown under variable environments. To minimize such confounding effects, agro-morphological characterization was performed with the same varieties at locations where farmers were invited for their assessment. The difference therefore should be explained as the degree of correspondence. "Chhatre" is another variety named after its leaf shape and size. In theory, this should measure wide and longer leaf size, which in actuality measured from the second widest leaf size. Farmers distinguish three varieties based on names created after the numbers of cormels they produce. When counted the same varieties produced the largest number of cormels per plant among the varieties under test. Those varieties of *Xanthosoma* spp. are known for aerial parts and assumed to produce very low cormel yield. The results show that both varieties produced the lowest cormel yield. Like farmers named varieties against petiole and sap color the research measured the same. "Hattipow", "Khari" and "Thado", which farmers' name according to their corms shape and size, show exact results when researchers measured against those traits. Farmers name "Gante" for varieties that attain 'short plant height', in actuality were measured as tall as all other varieties.

There seems higher degree of correspondence between farmer–named varieties and agro morphological measurements. The high degree of agreement exists when farmers create names based on some 'distinct' variety trait. In general, this shows that 'names' approximate diversity better especially when they are created based on distinct morphological characters. In some cases, such criteria may be misleading when such traits are affected by environment factors. A variety named after plant height may be different when grown under variable environments.

Table 5.9 Morphological characteristics of selected taro diversity tested in diversity block at Kaski, Nepal, 1999.

Varieties	Petiole colour	Corm manifestation	Cormel shape	Corm shape	Corm-size	Corm sheath	Cortext colour	Skin colour	Flesh colour	Bud colour
Burmeli pindalu	Green	1	5	5	3	1	white	white	white	white
Bhaishikhutte	Green	0	0	7	5	2	white	white	white	white
Chhatre/juke	Green	1	1	5	3	2	pink	pink	w.pink	pink
Dudhe Karkalo	Ashy white	0	0	3	3	1	white	green	white	white
Gante	Black	1	2	5	3	2	white	white	white	white
Hatti pau pidalu	Light green	0	0	7	3	2	white	white	white	white
Kalo karkalo	Dark purple	1	0	3	3	2	pinkish	purple	pinkish	red
Khajure pindalu	Green	1	99	2	3	2	white	white	white	white
Khari	Green	1	6	6	3	3	white	white	white	white
Khujure Kalo	Dark green	1	2	2	3	2	white	white	white	white
Khujure rato	Green	1	4	2	3	2	pink	white	pink	pink
Khujure seto	Green	1	99	2	3	2	white	white	white	white
Lahure karkalo	Green	1	3	2	3	3	white	white	white	white
Panchmukhe	Green	0	0	7	5	2	white	white	white	white
Panchmukhe seto	Green	1	1	8	3	2	white	white	white	white
Rato mukhe pindalu	Green	1	4	2	3	3	white	pink	pink	pink
Rato or Raate	Green	1	4	3	3	2	white	pink	w. pink	pink
Satmukhe	Green	1	6	6	3	3	white	white	white	white
Thado	Green	1	0	6	3	3	white	white	white	white

99: not explained

Table: 5.10 Main plant and root characteristics of taro diversity tested in a diversity block in Kaski, Nepal, 1999.

Varieties	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	No. side cormel per plant	Cormel yield (g/plant)	No. of main corm per plant	Corm yield (g/plant)	Total corm yield (g/plant)
1. Bhaishikhutte	149 ± 7.91	79 ± 2.0	55 ± 1.5	3.2 ± 0.9	55 ± 21	2 ± 0.5	1863 ± 265	1918
2. Burmeli pindalu	272 ± 18.1	73 ± 2.5	50 ± 2.4	8.6 ± 2.2	565 ± 258	1 ± 0.0	1435 ± 338	2000
3. Chhatre/juke	144 ± 12.5	69 ± 3.2	47 ± 1.8	24.2 ± 2.5	825 ± 107	2 ± 0.4	580 ± 74	1405
4. Chhaure	91 ± 8.2	44 ± 4.3	29 ± 2.8	18.8 ± 4.4	600 ± 178	2 ± 0.3	370 ± 89	970
5. Dudhe Karkalo	88 ± 5.2	53 ± 1.5	44 ± 2.0	0 ± 0.0	0 ± 0	1 ± 0.3	213 ± 46	213
6. Gante	125 ± 8.4	58 ± 4.7	38 ± 2.7	14.3 ± 1.3	365 ± 16	1 ± 0.3	175 ± 25	540
7. Hatti pau pidalu	144 ± 10.1	66 ± 7.4	46 ± 3.0	5.0 ± 1.3	105 ± 30	1 ± 0.3	780 ± 134	885
8. Kaat	106 ± 3.5	41 ± 2.1	33 ± 1.5	10.0 ± 2.0	138 ± 38	3 ± 0.8	358 ± 200	496
9. Kalo karkalo	92 ± 8.03	60 ± 7.6	29 ± 8.0	5.0 ± 1.0	136 ± 24	3 ± 0.6	350 ± 70	487
10. Khajure pindalu	136 ± 4.3	58 ± 3.2	45 ± 1.9	36.0 ± 3.7	950 ± 96	1 ± 0.3	219 ± 62	1169
11. Khari	150 ± 10.6	76 ± 9.4	57 ± 7.4	25.0 ± 5.1	1992± 346	1 ± 0.0	1900 ± 450	3892
12. Khujure Kalo	83 ± 9.6	35 ± 4.2	23 ± 2.5	16.0 ± 4.0	425 ± 75	2 ± 0.5	188 ± 88	613
13. Khujure seto	139 ± 6.2	68 ± 5.3	48 ± 3.4	48.0 ± 7.8	1275 ±291	2 ± 0.2	288 ± 68	1563
14. Lahure karkalo	57 ± 3.28	31 ± 2.1	21 ± 1.6	3.7 ± 0.9	87 ± 58	1 ± 0.3	92 ± 8	179
15. Panchmukhe	136 ± 8.5	70 ± 4.9	52 ± 3.1	5.5 ± 0.5	146 ± 18	1 ± 0.2	1125 ± 288	1271
16. Panchmukhe seto	98 ± 3.5	57 ± 4.4	41 ± 3.2	9.7 ± 2.0	197 ± 45	2 ± 0.4	504 ± 77	701
17. Rato mukhe pindalu	117 ± 6.3	61 ± 7.1	42 ± 3.9	15.0 ± 3.0	408 ± 136	3 ± 0.6	388 ± 108	796
18. Rato or Raate	147 ± 11.7	55 ± 5.8	36 ± 3.7	19.5 ± 3.1	550 ± 100	1 ± 0.0	325 ± 150	875
19. Thado	126 ± 12.3	47 ± 4.0	34 ± 3.4	24.3 ± 7.1	950 ± 525	1 ± 0.0	450 ± 226	1400

Note: Average value of five measurements with ± value indicates standard error of the mean.

Table: 5.11 Correlation matrices among researchers' descriptors used to characterize taro diversity in Kaski, Nepal

Measured trait	Code no	1	2	3	4	5	6	7	8	9	10	11	12	13
Plant height	1	X												
Leaf length	2	0.803***	x											
Leaf width	3	0.794***	0.915***	x										
Cormel number	4	0.415*	0.153	0.187	x									
Petiole colour	5	0.189	0.23	0.306	-0.264	x								
Corm manifestation	6	-0.139	-0.23	-0.185	0.232	0.518	x							
Cormel shape	7	-0.119	0.015	-0.163	0.419*	0.06	0.458*	x						
Corm sheath	8	-0.084	-0.274	-0.144	0.062	0.323	0.474**	0.081	x					
Cortext colour	9	0.09	-0.015	-0.059	-0.025	0.346	0.239	-0.122	-0.18	x				
Flesh colour	10	0.201	0.004	-0.073	0.011	0.288	0.331	0.034	-0.02	0.721***	x			
Bud colour	11	0.201	0.004	-0.073	0.011	0.288	0.331	0.034	-0.02	0.721***	1.00	x		
Skin colour	12	0.337	0.181	0.097	-0.029	0.225	0.171	-0.131	-0.13	0.520*	0.807***	0.807***	x	
Cormel yield	13	0.462*	0.3	0.348	0.805***	-0.208	0.232	0.221	-0.02	-0.053	-0.06	-0.06	-0.072	x
Corm yield	14	0.566**	0.712***	0.717***	-0.128	0.092	-0.326	-0.33	-0.22	-0.042	-0.143	-0.134	-0.039	0.278

*** indicates different at 1% level of significance,
** indicates difference at 5% level of significance,
* indicates differences at 5-10% level of significance, other values are statistically insignificant.

5.4 Discussion and conclusions

Nepali farmers have been growing different named taro varieties from the *Tarai* plain through to the mid and high hills. The amount of diversity, however, differed by agro-ecological zones; greater diversity was evident in the mid hills. This diversity is distributed under variable moisture and fertility regimes. The study reveals that farmers have played active roles in shaping diversity while adapting to the local conditions. The persistence of minimal diversity on the *Tarai* plain shows that diversity is affected by environment and management factors. The lower amount of diversity at high hill is related to adverse climatic conditions combined with lack of farmers' access to new varieties. Thus rich diversity is maintained to meet ecosystem requirements, local food requirement and consumers' demand. A rich food tradition associated with ethnicity has enhanced this diversity on-farm.

Along with the assessment of diversity, understanding evenness and dominance of this diversity is important. The Simpson Diversity Index and four squared analysis showed that more than 52% varieties are grown just by very few households while some 31% are grown either by many households in small areas or by few households in larger areas. In reality, some 16% of the total varieties are grown by many households in relatively larger areas. This result can have manifold interpretations especially for those grown at small scales and by a few households. There could be different schools of thought regarding the maintenance of diversity on-farm. One school of thought could be that they are already on the verge of extinction and need conservation attention. The other argument could be that varieties grown for specific purposes and in small scales and therefore will continue to exist for a long time because the areas farmers have allocated them are often marginal and do not compete with other options available to farmers. In other words, these varieties are the only best option available for niche environment. It may be that these varieties might be grown more widely if demand is created through improved access to information and planting materials locally. It implies that varieties grown by many households at larger scales could be affected which may restructure existing diversity. The scenarios may change when farmers have a basket of choices suitable for different ecosystems. Farmers might discontinue with presently grown varieties if they do not remain competitive with introduced varieties.

The present study asserts that local knowledge and diversity exist together. Farmers who cultivate diverse taro over a wide environment and management conditions hold more ecological and botanical knowledge than those growing few varieties under confined environments and cropping systems. Unlike high hill and *Tarai* farmers cultivating limited diversity under certain environments or niches the mid hill farmers cultivating rich taro diversity under varied environments and niches also hold rich knowledge. This knowledge also affects farmers' accuracy in distinguishing diversity. Farmers consistently distinguish varieties with names created after distinctive traits. In some instances, farmers distinguish diversity by names created after widely known location, animals and other objects, which resemble similar characteristics. The ways farmers create names can have manifold implications to diversity management on-farm no matter if farmers consistently distinguish diversity by names. If farmers were consistent then names could be used as a unit of diversity measurement. If farmers were inconsistent it can therefore be predicted that names carry information related to origin, area of adaptation and so on. If the farmers are inconsistent in naming varieties this information could lead further investigation regarding the basis of farmers' naming varieties.

In terms of morphology and quantitative measurement, there is a high degree of correspondence between farmer-named varieties and their actual measurement. In terms of allozyme variation farmer-named varieties clustered differently (Bajracharya *et al*., 2000). The researchers reported lack of correlations between morphological traits and isozymic variation (Lebot *et al.,* 1998; Xixiang, *et al.,* 2001). Different studies generally demonstrate that even though varieties are morphologically similar, farmer–named varieties are genetically different and therefore, farmers are consistent. The present research shows that taro varieties express their properties differently when grown away from their traditional habitats (Chapter 9). An apparent effect was seen particularly in the shape and size of the corm and cormel. Similar stories are found among Ethiopian farmers. Farmer–named varieties of one location are distinguished with different names owing to changes in emphasis on different qualities. In some villages a variety is called "white" while in others farmers recognize the same variety as "early" (Tanto 2001). Tesfaye and Ludders (2003) found similar evidence in Ethiopia for ensete, a clonally prorogated crop, for which a few varieties assumed different names at different locations. Giving different names for the same variety when grown in different environments, which is often found in clonally propagated species, could mean that farmers adapt their naming systems to the local context. Evidence shows that farmers distinguish varieties according to variety-specific distinct traits, especially morphological, agronomic, adaptive and post-harvest characteristics. Thus variety names have been the prime basis for farmers' management of taro diversity on-farm.

CHAPTER 6: FOOD CULTURE AND TARO DIVERSITY

"Considering food as a "driving force" for conserving biodiversity, we cannot just be food lovers ... we must be there where it is most at risk as in the developing world" - Carlo Petrini, Slow Food, October 2000, BBC Online.

In this chapter, research results on food traditions and local uses of taro diversity are described. The ways food value could be added are discussed. Research results on recipe development are presented. The chapter begins with the review of traditional dishes prepared from different parts of the taro plant. The roles food traditions can play in conserving diversity on-farm are discussed. The implications of increasing demand for such value added dishes for diversity conservation on-farm are discussed.

6.1 Introduction

Many cultures conserve varieties for their eating value rather than for their better yield under particular environmental conditions (see examples below). This maintenance of agro biodiversity indirectly serves to maintain cultural traditions. Taste for food is a powerful selective force in the maintenance of genetic diversity of various crop species. These varieties are often maintained in home gardens, not widely available commercially and generally grown on a small scale.

Taro (*Colocasia esculenta* (L.) Schott) is widely used in the tropics and subtropics and much of the diversity within the crop is still being maintained by farmers and local communities. Taro belongs to the genus *Colocasia*, within the sub-family *Colocasioideae* of the monocotyledonous family *Araceae*. Cultivated taro is classified as *Colocasia esculenta*, and the species is considered to be polymorphic (Onwueme, 1999).

Taro is used in a variety of local Nepalese dishes which utilize leaves, petioles and corms or cormels. Dishes include as a vegetable, in a curry, boiled and/or fried. Nepalese farmers classify taro either as ‘Karkalo’ (leafy taro) or ‘Pindalu’ (corm taro) depending upon the part being used for food (see Chapter 4). Taro is grown predominantly as a subsistence vegetable crop, although some popular local varieties (‘Ujarka’, ‘Hattipow’ and ‘Khujure’) are marketed for cash generation.

Certain traits, such as acridity, are preferred for specific dishes, while for other dishes acridity is a trait to be avoided. Contact of the raw taro corm with the mouth or skin causes itchiness, acridity and discomfort. The raw leaves and petioles can also cause acridity (Tang and Sakai, 1983; Nixon, 1987; Bradbury and Holloway, 1988), resulting in swelling and soreness (Bradbury and Nixon, 1998), the effect of which is neutralised by cooking. The degree of acridity greatly influences farmers’ selection of taro local varieties. The variety ‘Jaluka’ is recognised for its high level of acridity and consequent use in specific dishes e.g. *masaura*.

Past studies have shown that farmers will maintain crop local varieties if these are valued either for economic, cultural, social, or ecological reasons (Rijal, *et al*., 1998; Brush and Meng, 1998; Zimmer and Douches, 1991; Bellon and Taylor, 1993). One example is maize, different varieties of which are cultivated by the Mayan people of the Yucatan, and grown for specific food purposes (Lope-Alzina, 2004). The dough of the *Xnuk nal* variety is considered the best for making tortillas due to its suitable consistency for shaping tortillas and its good taste. The *Xmejen nal* variety was used for its taste and consistency as thick maize pancakes. The same research also studied varieties of squash: the variety *Tzol* (*Curcubita pepo* L.) was maintained for no other purpose than taste.

Another case is that of women farmers in Rwanda who manage over 600 varieties of beans (*Phaseolus vulgaris*) (Shellie, 1990). Here, hard coated beans have been systematically selected against, thereby decreasing the cooking time of the beans. This was verified through genetic analyses, which found low variability for this trait.

Other specific examples are the conservation and use of different banana varieties in Africa (Sharrock and Frison, 1998), rice in Indonesia (Setyawati, 1996) and Thailand (Piyasilp and Khusantear, 2003), cowpea in Cameroon (Kitch *et al*., 1998), potatoes in the Andes in southern Peru (Zimmerer, 1991), sweet potato in Indonesia (Prain *et al*., 2003), cassava in South America (Boster, 1984; Zent, 1999) and sorghums in Africa (Chitsika and Mudimbu, 1992), Asia and North America (Undersander *et al*., 1992).

It has been suggested that the demand for crop local varieties and their derived products may be expanded through improved markets that promote consumers' awareness and policy support (Jarvis and Hodgkin, 1997). Locally prepared products have to compete strongly to attract new consumers, especially in urban areas where the inhabitants are already exposed to a variety of other choices of food dishes. The elaboration of traditional dishes, combined with improved access to associated information (for consumers), provides incentives to farmers for their cultivation on-farm.

The specific issues addressed in this chapter are:

(a) the elaboration of taro dishes using different local varieties and the assessment of these dishes by a taste panel

(b) the importance of acridity in cooking and the conservation of acrid local varieties in agro-ecosystems

(c) an investigation into the different uses of local taro varieties in Nepalese cuisine.

6.2 Method

6.2.1 Site description

The information on food traditions discussed in this article was collected from three different villages in Nepal (Chapter 2). The environmental and socioeconomic characteristics of the study areas are summarised in Chapter 2.

6.2.2 Data collection

Data were gathered through researchers' field experience, observations and focus group discussions (FGD) with farmers. In each FGD, 9-10 "nodal farmers" (those farmers which are innovative, knowledgeable, maintain a high number of crop local varieties and also provide services (Subedi *et al*., 2002) were involved. The majority of farmers who participated in the discussion were women who had the most in-depth knowledge of food traditions; known men cooks of the area were also invited. Descriptions of meals were then gathered through these observations and FGDs.

6.2.3 Taste evaluation of elaborated dishes

Locally identified taro dishes were tasted by a panel of farmers, urban male and female cooks, and professional cooks. Topical FGDs were held with experts such as cooks, marketers and service providers. Since marketers are familiar with consumers' preferences, inclusion of their perspectives in the research process was ensured. The scope and need for the elaboration of local dishes was explored. The panel identified potential dishes for elaboration. Locally known taro local varieties from Kaski and Bara were used in popular urban dishes, namely curry, dip fry and *Samosa*. Three popular local varieties, 'Panchamukhe' and 'Hattipow' from Kaski and 'Ujarka' from Bara were chosen. They were cooked with fish, mutton and legumes. The snack dish *Samosa* was tried using 'Ujarka', a known variety, in place of potatoes. Different combinations of dishes tested are presented in Table 6.1. These underwent taste evaluation.

To ensure consumers' representation, three panel groups representing farmers-custodians, urban housewives and expert (hotel) cooks were assembled. In urban and rural societies women (most known cooks are still women) were invited for the evaluation. Other members already familiar with traditional dishes were also invited. Hotel cooks, familiar with the wide range of consumers' taste, from local elites through to outsiders, were also invited. The experiment was conducted at the Pokhara Tourism Training Centre and involved local farmers and panellists from around Pokhara.

Through the discussions, five parameters-namely taste, colour, appearance, texture and aroma were considered. Prior to the dishes being served, panel members were briefed on the evaluation system. They were asked to evaluate individual dishes either as good, medium or poor. Later, this individual ranking was coded as 5 for good, 3 for medium and 1 for poor. Panel preferences were estimated using a formula: individual panel response x individual score for each good (5), medium (3) and poor (1) category. The relative score for individual dishes: Panel members' response (n) given to individual dishes = 5 x n + 3 x n + 1 x n, which is divided by the total number of panel members (N) involved (Singh, 2001):

$$\text{Preference ranking} = \sum_{i=1}^{n=N} \frac{5 \text{ x n} + 3 \text{ x n} + 1 \text{ x n}}{\text{N}}$$

6.2.4 Estimation of acridity

Among other traits, acridity in taro becomes most important while preparing certain dishes. Nepali farmers sometimes collect wild taros (Jaluka) for its acrid character. It was learned that strong acridity produces a strong and delicious pickle. However, some treatments are done to make best use of this character. Less acrid varieties are consumed boiled or as vegetables. Kaski farmers were invited to share their experience on acridity for local varieties included in this study.

Altogether 19 taro varieties were evaluated in a "diversity blocks" conducted at the Agricultural Research Station, Malepatan (900 m) and in Begnas of Kaski district. A group of nine men and nine women farmers identified descriptors for taro, including acridity. Each group ranked local varieties for their acridity levels on a scale 1–4, where 4 indicated the lowest acridity as described by Singh *et al*., (2001). The acridity index, estimated as: Panel member given score (4 or 3 or 2 or 1) x number of response given to individual categories divided by total number of panel members. The relative index values were calculated individually for all local varieties.

6.2.5 Data analysis

In this study, four types of data sets have been used: 1) inventory of items included in individual meals; 2) organoleptic data on taro dishes; 3) relative ranking data on acridity as recalled by farmers; and 4) variety suitability data for individual dishes. These sets of data are analysed in different ways. The weighted means for local varieties and local dish items were analyzed. Descriptive analyses of central tendency and dispersion were applied to estimate and describe the variations for individual characters (Steel and Torrie, 1988). Other researchers applied descriptive statistics, Pearson correlation and principal component analyses while assessing taro diversity (Manzano *et al*., (2001). In this study, data are analysed using descriptive statistics and Pearson correlation techniques. The similarity of local varieties in terms of local uses is presented using a dendrogram. The analyses were performed using Minitab 13 software package.

Farmers' inventory dishes that compose individual meals are tabulated by study area and time of service; both traditional and introduced items are inventoried. The weighted mean for organoleptic assessment was estimated to obtain relative ranking. Farmers' suitability assessment of taro diversity against traditional dishes was performed with a group of people. The standardised scores were estimated to compare preferred varieties for different items. The aim had been to determine whether varieties are preferred for specific items or generally. Correlation matrices were performed to determine the relatedness of local varieties considering farmers' suitability response to food items and vice versa. These correlations may suggest whether or not the local food items are variety-specific.

6.3 Results

6.3.1 Nepalese food tradition

Nepalese foods can be grouped into 'primary' and 'secondary' meals, as suggested by Douglas (1997). These main meals are here termed 'primary meals'. A complete meal consists of dishes from cereals, legume, vegetable, milk or 'ghee' (clarified butter) and pickles. The most common meal, both in urban and rural settings, consists of 'Daal' (lentil soup), 'Bhat' (boiled rice or maize grits or gruel) and 'Tarkari' (curry or vegetable). Pickles with hot and sour tastes are other accessory components of meals. Taro is used a vegetable, in a *curry*, with *Daal* as well as a snack or pickle.

Taros and their preparations are introduced into secondary meals[i] throughout the study areas. Taro preparations alone serve as complete snacks and a vegetable. Only recently taros have been mixed with other species' products to introduce dishes with new tastes, since taros prepare several processed vegetable products from roots, petioles and leaves that can be supplied throughout the year. A brief overview of local dishes served at different times of the day is presented in Table 6.1.

Table: 6.1 Descriptions of the regular cuisines of Jumla, Kaski and Bara research sites, Nepal.

Meals in priority order, I= High	Study areas		
	Jumla (Mountain)	Kaski (Mid-hill)	Bara (*Tarai*)
III. Breakfast or *Bihanko Khaja* (6-8am)	a. Tea © + b. Boiled potatoes/ c. Millet bread/ d. Roasted barley flour **e. Noodles** f. Left over meals served to children	a.Tea ©+ b. Boiled egg (O) c. Puffed corn/ d. Puffed soybean or **d. Noodles or** e. Milk only f. Left over meals served to children	a. Tea © + b. Boiled egg (O) c. Beaten rice+yoghurt+Curry / **d. Biscuits /** **e. Noodles/** **f. Bread /Loaf/** g. Milk only or h. Left over meals served to children
I. Morning meal or *Bhat* (9-10am)	a. Vegetable curry ©+ b. Beans soup/ c. Fermented dish (OS) c. Boiled rice / d. Millet bread e. Whey (O) f. Yogurt (O)	a. Vegetable curry © b. Legume soup/ c. Fermented Dish (OS) d. **Paraboiled rice** / e. Boiled maize grit / f. Millet porrige / g. Milk / whey+ h. Pickle +	a. Vegetable curry ©+ b. Legume soup+/ c. Fermented Dish (OS) d. Boiled rice©+ e. Yogurt or whey (O) f. Fried potatoes (F)+ **g. Nutrella (OS)** h. Pickle + i. Ripen mango (S) +
II. Midday snack / *Diusoko Khaja* (2-3pm)	a. Tea ©+ b. Millet bread / c. Buckwheat bread / d. Boiled potatoes / e. Puffed corn + Whey f. **Noodles**	a. Tea ©+ b. Beaten rice +Yogurt + Curry c. Sweets + Curry / d. *Samosa* + Yogurt / e. Biscuits/bread / f. Puffed corn+ Whey/ g. Puffed rice + Pickle h. **Noodles** **i.** Wheat chapati + Vegetable curry	a. Tea ©+ b. Beaten rice+Yogurt + Curry/ c. *Samosa* + Yogurt/ d. Sweets + curry / e. Boiled potatoes + Whey/ f. Puffed maize + Whey/ g .Puffed rice+Fried potatoes/ h. Biscuits/bread i. **Noodles** j. Wheat chapati + Vegetable curry
I. Evening meal / *Belukako Khana* (6-7pm)	a.Vgetable curry / b. Beans soup+© c. Millet bread d. Buck wheat bread / e. Boiled rice (P) f. Barley + millet bread/ g. Wheat bread h. Whey + i. Meat (OC) j. Fish ® k. Egg ®	a. Vegetable curry / b. Black gram soup ©/ c. 'Masaura' (OS)/ **d. Nutrella (OS)+** e. Maize grit / f. Wheat bread / g. Millet porrige / h. Whey + i. Meat (OC) j. Fish (FSS) k. Egg ®	a. Vegetable curry © b. Lentil soup ©+/ **c. Nutrella (F)** d. Wheat bread / e. Cooked rice / f. Milk or whey+ g. Meat (OC) h. Fish (FSS) i. Egg (F)

Note: © = common element, O = optional dishes, ®=rarely served dish, FSS=frequently served dish in particular season, OC=Dish served in special occasion, OS=Off-season served dish, /=Alternative or optional element of a meal, +/=Dish served along with or with alternative dish. Dishes in bold are processed foods or those foods replacing local foods

.Source: Focus group discussion (2002).

Taros and their preparations are becoming increasingly popular among rural and urban consumers including farmers because i) taro produce higher yield, ii) taro's all parts can be used, iii) taro is easier to cultivate, iv) taro has low risk of crop failure and damage, v) taro prepares delicious dishes, and vi) taro grow well under varied cropping systems and environments. It is therefore important to document local botanical knowledge, their potential integration into Nepalese food dishes and prospects of increasing consumers' demand through adding values. Along with increasing local uses, increasing demand for taro enhances diversity on-farm. The following sections present local knowledge held by farmers of the study areas.

6.3.2 Utility value of taro diversity

Farmers select varieties according to their use values and specific preferences. Table 6.2 presents locally described recipes, their literal translation, the most preferred plant parts for individual recipes, the most preferred varieties along with those least preferred for individual recipes. Farmers categorically identified 13 food recipes prepared from taro. Some varieties are more preferred for specific plant parts whereas others for multiple parts and some varieties for all parts. Some of the recipes are prepared from fresh leaf or petiole while others from corm or cormels. The recipes could be served fresh or in processed forms, especially during the dry season when vegetable supplies are limited.

Since food preference also differs by gender, it is important to understand the preferences of varieties by male and female farmers. At the same time, food preference may differ by ethnicity and the amount of taro diversity by wealth category and ethnicity.

Table 6.2 Classification of taro diversity by use value in Kaski, Nepal

Use value	Translation	Plant part used↔	Best preferred varieties by preference ranking	Least preferred local varieties according to preference ranking
1. Karkalo ko sag/ hariyo gava [1]	Green vegetables	Young leaf/ petiole for vegetable	Khujure, Ratomukhe, Khari, Thagne, Jaluka (wild), Seto mukhe, Satmukhe,	*Hattipow* pindalu , Lahure pindalu, Dudhe karkaklo
2. Pindalu ko tarkari	Taro curry	Crom and cromels	Kaat, Chhatre, Rato mukhe, *Hattipow*, Panchmukhe seto, Bhainsikhutte, Khari rato, Khujure, Bermeli, Khari, Seto and Rato Khujure, Kalo khujure, Panchmukhe,	Jaluka, Kalo Karkalo, Burmeli, Lahure karkalo,
3. Pindalu ko dal	Taro pulse soup	Crom and cromels	*Hattipow*, Kaat, Khujure, Khujure seto, Panchmukhe seto, Bhainsikhutte, Lahure, Khari rato, Rato mukhe, Rato khujure, Chhatre	Dhude karkalo, Gante dalle
4. Masaura[2]	Dried nugget	Petiole	Khujure rato, *Hattipow*, Chhatre, Rato mukhe, Panchmukhe seto, Bhainsikhutte, Khari	Dudhe Karkalo, Kalo Karkalo, Lahure karkalo, *Hattipow*, Bhaisikhutte
5. Khasaura[3]	Dried young leaves	Young leaf	Khujure rato, Chhatre, Bhainsikhutte, rato mukhe, rato khujure, Panchmukhe seto	Lahure karkalo, Burmeli, Dudhe Karkalo, Kalo Karkalo
6. Gava[4]	Boiled and dried young leaf	Young leaf	Khujure, Ratomukhe, Thagne, khari	Dudhe Karkalo, Lahure karkalo, Kalo Karkalo, *Hattipow*
7. Achar[5]	Pickle	Petiole	Dudhe karkalo, Kalo karkalo, Lahure pindalu, Burmeli	All remaining varieties are not good for this purpose
8. Khaja usinera	Snacks (boiled/baked)	Crom or cromels	Kalo pindalu, Chhaure, Khujure, Seto Khujure, Lahure pindalu	Jaluka, Dudhe karkalo
9. Tandre sukuti[6]	Dried petiole curry	Petiole	Khari, Khujure, Kaat, Rato danthe, Setomukhe, Thagne, Kalo karkalo, Satmukhe, Thadomukhe, Panchmukhe rato, *Hattipow*	Dudhe karkalo,Lahure karkalo, Burmeli
10. Koresho[7]	Grated corm	Crom	*Hattipow*, Panchmukhe seto, Bhainsikhutte, Thangne, Khari, Lahure pindalu	Dudhe karkalo, Kalo karkalo, Lahure karkalo, Burmeli, Seto and Kalo Khujure
11. Paise karkalo[8]	Coin-shaped vegetable	Petiole/stem	Khujure, Khujure kalo, Bhainsikhutte, Panchmukhe seto, Khari, Hatti pau	Dudhe karkalo, Lahure karkalo, Kalo karkalo, Burmeli
12. Siura[9]	Tender shoots for green vegetable	Young shoots	Khujure, Khujere kalo, Ratomukhe, *Hattipow*, Thagne	Lahure karkalo, Kalo karkalo, Dudhe karkalo
13. Bhujuri[10]	Sliced petioles in an irregular shapes	Petiole	Khari, Thagne khari, Satmukhe, Panchmukhe seto, Bhainsikhutte, Thadomukhe	Dudhe karkalo, Kalo karkalo, Lahure karkalo

Main reasons for farmers to grow it; 1=A popular summer green vegetable prepared with lemon. Half portion of young leaf is rolled up, wilted overnight and cooked with curry paste; 2=Chopped petiole is mixed with black gram flour paste and triangular balls are made and dried for special masaura curry; 3=dried young leaves packed for off-season vegetable; 4= Half portion of young leaf is rolled up, boiled and sun-dried, and preserved for eating off-season; used for gava curry; 5=Petiole are cut into pieces, wilted and pickled for long. Taro varieties with low levels of calcium oxylate crystals is used to eat as raw as salad; 6=Long petiole of taro is cut vertically into small threads, weave like ladies hair, hanged in front of window for sun-drying and stored for off-season. It is used to cook tandre curry after soaking into hot water and cooked like meat; 7=Dried leaves packed for eating off-season; 8=Petiole cut cross-sectionally that looks like small coins and dried under shade; 9=young green shoots for green vegetable; 10=It is prepared like pasie karkalo but sizes are like *Bhujuri*.

6.3.3 Diverse food dishes prepared from taro

Different dishes are prepared from leaves, petioles and corm or cormel. Farmers inventoried 19 dishes, the majority of which were prepared from leaves.

A dish may be prepared alone from taro products or combining with others. *Phando* and *Masaura* are examples of combined dishes. There were both common and site-specific items. *Badi*, *Dudhe gava*, *Phando* of Jumla, *Masaura*, *Achar*, *Koresho*, *Khasaura* of Kaski and *Pakora*, *Samosa*, *Chhokha* in Bara are examples (see Table 6.3).

As shown in the Table, taro is used in preparing a variety of food dishes across all study areas. However, food dishes at locations were different. The number of food dishes prepared varied according to the number of varieties grown. More food dishes are prepared in areas where farmers have been maintaining rich diversity. The opposite was not always true: farmers growing a few varieties still prepare a variety of food dishes in Bara and Jumla.

Farmers maintain rich taro diversity for its useful parts. Some varieties are more preferred for petiole and leaf and others for cormel, or corms. Such specialised preferences have enhanced the maintenance of diversity on-farm. Taro diversity persists along with the variation of food dishes.

Table 6.3 Description of traditional dishes by taro plant parts at Jumla, Kaski and Bara research sites, Nepal.

Local dishes	Description
Leaf items: *Baadi*	Meat ball like structure prepared from chopped petioles or young leaves are mixed with meshed potatoes and dried balls. A popular item in Jumla.
Bhujiya	Dip fried dish prepared from leaf, petiole or corm by peeling off unwanted portions like vein, bark etc. A popular item of Kaski.
Dudhe gava	Tender leaves are boiled with milk and dried items are stored for off-season serving. A popular item of Jumla.
Gava	First half of young leaves rolled up, boiled and semi-dried under shed, and preserved for off-season. A popular item in Kaski.
Hariyo gava	Half portion of young leaf is rolled up, wilted overnight and cooked with curry paste. Lemon is poured to neutralize acridity. Common item.
Hariyo saag	Fresh leaf boiled vegetable, Common across all locations but more popular in Kaski and Jumla.
Khasaura	Dried young leaves are stored for off-season vegetable. A popular item of Kaski.
Koresho	Dried leaves are packed for eating off-season. A popular item of Kaski.
Siura	Young shoots picked up for fresh green vegetable. Common item
Sukayeko paat	Dried leaves are eaten during off-season. A popular item of Jumla, Kaski.
Petiole items: *Achar*	Petioles are cut into pieces, wilted and pickled. Local varieties with low acridity are directly eaten raw as salad. A popular item of Kaski.
Bhujuri	Prepared like coin shaped chopped petiole of uniform sizes, Kaski.
Paise karkalo	Petiole cut in small pieces in cross-section, which then dried under shade. A popular item of Kaski.
Tandre sukuti	Taro petioles are cut into small threads, braided like pony tail & hung in Baranda for off-season consumption, Native to Kaski.
Corm or Cormel: *Chhokha*	Peeled off boiled corms are meshed and mix thoroughly with spices as desirable and add lemon if tastes acrid, Native to Bara.
Pakaura	Round or squared chopped corms are dipped in a legumes paste and dip fried mixed with spices and salt, as desired. A popular item of Bara.
Phando	Boiled corm or cormel when meshed is mixed with wheat flour or legumes powder, served any time of the year. A popular item of Jumla.
Samosa (Snack item)	Hexagonal shaped dip fried dish prepared mixing with cut onions, wheat flour and mesh potatoes or taro corm. A popular item of Bara.
Ushinera (Boiled)	Cormel or corm are boiled and served as mid-day snack. A popular item of Kaski & Jumla

6.3.4 Special dishes require specific varieties

Farmer preference for taro local varieties was found to be linked to the traditional dishes mentioned previously. Based on weighted mean, variety preferences against local uses are grouped into six categories. The varieties with greater weighted mean (n>50) are termed the most preferred ones as against lower mean values (n<10). A higher means increased use values and vice versa. “Khujure” and “Chhaure” were ranked as best local varieties for ‘multiple uses’. “Kalo karkalo”, “Lahure”, “Panchamukhe rato” and “Hatipow” ranked in fourth in the category. On the contrary, “Gante”, “Dudhe karkalo” and “Thaune” had lowest values indicating ‘limited uses’. “Dudhe karkalo” for example, is chosen mainly for a pickle item.

Of the varieties ‘Khujure’ and ‘Chhaure’ were ranked the highest. ‘Kalo karkalo’, ‘Lahure’, ‘Panchamukhe rato’ and ‘Hattipow’ ranked in fourth in the category. ‘Gante’, ‘Dudhe karkalo’ and ‘Thaune’ obtained the lowest values indicating their ‘limited uses’; for example, ‘Dudhe karkalo’ is used mainly as a pickle item and appreciated for its low acridity (Table 6.4).

Different varieties clustered together according to their suitability for individual food dishes. Varieties with greater values can be used interchangeably used to prepare desired food dishes; farmers can select any variety as a substitute. However, varieties with multiple uses do not necessarily substitute for varieties with specific uses. Despite greater preferences, ‘Khujure’ does not necessarily make delicious pickle like that prepared from ‘Lahure and ‘Kalo karkalo’.

Table 6.4 Farmers' ranking for taro varieties according to their preference to food dishes (Farmers=18), Kaski.

Local varieties	Masaura	Khaseura	Gava	Daal	Pickle	Boiled	Koreso	Tandre	Paise	Total
Khujure	7.0	7.0	7.0	7.0	0.06	7.0	6.61	7.0	7.0	55.67
Chhaure	7.0	7.0	7.0	7.0	0.06	7.0	1.17	7.0	7.0	50.22
Khujure kalo	6.22	6.61	4.17	4.17	0.06	6.22	1.17	7.0	6.22	41.83
Khujure seto	6.22	6.61	4.17	4.17	0.06	6.22	1.17	7.0	6.22	41.83
Kaat	3.89	3.33	3.61	4.17	0.06	3.89	3.61	4.17	3.89	30.61
Raate	3.89	3.33	3.17	4.17	0.06	3.89	3.16	4.17	3.89	30.61
Rato mukhe	3.89	3.33	3.61	4.17	0.06	3.89	3.61	4.17	3.89	30.61
Thado	3.89	3.33	3.61	4.17	0.06	3.89	3.61	4.17	3.89	30.61
Chhatre	3.89	3.61	1.50	4.17	0.06	3.89	3.61	4.17	3.89	28.78
Rato danthe	3.89	3.33	0.06	4.17	0.06	3.89	3.61	4.17	3.89	27.06
Kalo karkalo	0.11	0.11	0.11	7.0	6.61	3.89	3.89	0.11	0.11	21.94
Lahure	0.11	0.11	0.11	7.0	6.61	3.89	3.89	0.11	0.11	21.94
Hattipow	1.33	1.17	1.17	4.17	0.06	1.33	7.0	1.17	1.33	18.72
Panchmukhe rato	1.33	1.17	1.17	4.17	0.06	1.0	7.0	1.17	1.33	18.39
Panchmukhe seto	1.33	1.17	1.17	4.17	0.06	1.0	7.0	1.17	1.33	18.39
Bhainsi khutte	1.33	0.22	1.17	4.17	0.06	0.22	7.0	1.17	1.33	16.67
Gante	1.33	3.61	1.33	0.11	0.06	0.17	0.17	1.33	0.22	8.33
Dudhe karkalo	0.06	0.06	0.06	0.06	7.0	0.06	0.06	0.06	0.06	7.44
Thaune	0.17	0.17	0.17	0.17	0.06	0.11	3.89	0.17	0.17	5.06

Source: Focus Group Discussion, Begnas (2002)

The results show that cultivars with multiple uses are more preferred over cultivars that have limited uses.

6.3.5 Correlation matrices for taro varieties and local dishes

Out of 35 matrices carried for nine dishes, 16 cases showed strong positive correlations ($P \leq 0.001$). Those locally popular dishes strongly correlated to one another include: *Tandre: Masaura* (0.99), *Paise: Masaura* (0.95), *Tandre: Khasaura* (0.96), *Tandre: Gava* (0.86) (See Table 6.5)

The varieties with good petiole quality tend to produce tastier corms and cormels and vice versa. The analysis revealed a positive significant correlation between different dishes items. Local varieties suitable for *Gava, Masaura, Khasaura* are preferred also for *Tandre.* 'Dudhe' and 'Kalo karkalo' known for pickle making were least preferred for *Tandre.* The local varieties suitable for pickle also prepare *Koreso. Pickle* and *Koresho* correlated negatively with other items, except for *Daal* prepared from corms or cormels.

Correlations among the most diverse local varieties ranked for their locally popular dish items, (Panelist=18). The underlined figures are significant at 0.1% (Table 6.5).

Table: 6.5 Correlation matrices for among food dishes assessed by panel members (n=18)

	Masaura	*Khaseura*	*Gava*	*Daal*	*Pickle*	*Boiled*	*Koreso*	*Tandre*
Khaseura	<u>0.962</u>							
Gava	<u>0.892</u>	<u>0.869</u>						
Daal	0.395	0.286	0.424					
Pickle	-0.535	-0.506	-0.451	0.099				
Boiled	<u>0.853</u>	<u>0.810</u>	<u>0.764</u>	<u>0.693</u>	-0.126			
Koreso	-0.225	-0.361	-0.139	0.345	-0.227	-0.234		
Tandre	<u>0.996</u>	<u>0.961</u>	<u>0.868</u>	0.368	-0.520	<u>0.858</u>	-0.269	
Paise	<u>0.995</u>	<u>0.933</u>	<u>0.884</u>	0.433	-0.512	<u>0.866</u>	-0.182	<u>0.991</u>

Out of 171 total matrices carried out for local varieties, 30 cases showed significant positive correlations ($P < 0.001$). In terms of local uses, different farmers-named varieties positively correlated ($P < 0.001$). A positive correlation among several dishes would mean that some varieties are suitable for a wide range of food dishes. Varieties that are popular for *Paise* are preferred also for *Masaura, Khasaura, Gava, Tandre* and boiled. A weak or negative correlation indicates those varieties have specific uses. The matrices revealed by Pearson correlation are summarised in Table 6.6

Table: 6.6 Farmers' suitability assessment for different food dishes revealed by Pearson correlation, Kaski.

Local varieties	**Correlation Coefficient**
Khujure: Chhaure	0.91
Raate: Chhaure	0.80
Chhatre: Khujure seto	0.82
Chhatre: Kaat	0.86
Chhatre: Raate	0.90
Chhatre: Ratomukhe	0.86
Chhatre: Thado	0.86
Bhainshikhutte: Panchamukhe rato	0.98
Bhainshikhutte: Panchamukhe kalo	0.98
Bhainshikhutte: Hattipow	0.98
Thaune: Hattipow	0.86
Thaune: Panchamukhe rato	0.86
Thaune: Bhainshikhutte	0.85

'Thaune' thus strongly correlated with local varieties that produce corm or cormel. 'Dudhe karkalo', however, was weakly correlated with 'Khujure', 'Kaat', 'Raate', 'Rato mukhe' and 'Thado'.

On the basis of farmers' ranking, different local varieties formed five distinct clusters. "Khujure" and "Chhaure" were found most suitable across all the dishes items; "Khujure kalo" and "Khujure seto" similar. Likewise, local varieties "Kaat", "Raate", "Rato mukhe thado", "Chhatre" and "Rato danthe" clustered together. The most preferred local varieties for specific dishes and or least preferred for a variety of dishes were identified (Table 6.4). There are at least 2-4 most preferred local varieties identified for individual dishes. Clearly, farmers have categorically identified most suited local varieties for individual dishes. It also shows that farmers alternatively were using other local varieties except those that prepare pickle ("Kalo karkalo", "Dudhe karkalo" and "Lahure"). This analysis provided practical ways of identifying farmers' preferences among the local varieties they have been maintaining. Increased understanding on local uses along with their priority order, would guide formulate strategies related to research, development and conservation.

The local varieties with greater number of use values were generally preferred over those which have specific uses. The most preferred local varieties such as "Chhaure", "Khujure", "Khujure kalo", "Khujure seto", "Hattipow", "Ratomukhe", "Kaat, Raate" were grown at larger scales and by many households. By contrast, "Dudhe karkalo" which has specific use value was grown by many households but in a scale of few plants especially where other local varieties hardly grow, such as home garden. Similarly, "Thagne" prepares good *Koreso* and 'Gante' is known for *Khaserua.* Above results reveal following key points:

- Local varieties have distinct traits which determine their uses
- Local varieties prepare different dishes from individual parts
- Some local varieties strongly correlated when analysed with respect to traditional dishes and therefore can be used as substitute for one another.

6.3.6 Special dishes require specific plant parts

Table 6.7 shows farmers' assessment of plant parts for their local uses. The results show that not all parts of all varieties of taro are equally valued. Some local varieties are known for a single part while others for two parts. However, some local varieties are highly valued for all parts. The extent and distribution of taro diversity may be related to the value of plant parts. Some local varieties are more preferred for their corms or cormels while others for petioles and leaves. The most preferred local varieties are those which produce high quality corms, cormels, petioles and leaves. In most instances, local varieties that have multiple use values are grown widely under good environments such as *bari land.* In contrast, local varieties that are known for specific uses are grown under home garden on a small scale.

Table 6.7 Farmers preferred taro varieties and their plant parts, Kaski.

Use value	Local varieties
A. Use of plant materials	
Flower/inflorescence	Not reported by farmer
Petiole only	Dudhe karkalo[1]
Young leaf	Jaluka
Young petiole and cormel	Kalo karkalo[1], Lahure pindalu[1]
Main corm	Katt, Hatiipow, Khari, Thagne khari,
Corms and cormels	Ratomukhe, Chhatre
Cormels	Khujure, Rato Khujure, Khujure seto, Kalo Khujure [2]
All plant parts including leaf, petiole, corm and cormels	Chhaure, Satmukhe, Thado mukhe, *Hattipow*[3], Panchmukhe seto, Gante, Bhainsekhute, Panchmukhe, Khujure seto
Un-edible corm	Mane[4] and Jaluka
B. Economic value	
High market value for multipurpose uses	Hattipow
High corm yield	Hattipow, panchmukhe
Free from calcium oxylate crystals (low acridity)	Dudhe karkalo
Easy cooking corm/cormels	Lahure karkalo, Kaat
High protein content*	Gante (7.23%), Rate (5.3%), Khari (4.8%), Bhaisikhute (4.7%)

1 = Usually grown in small area near homestead by many households

2 = Usually grown in small area by a few household only

3 = Usually grown in large area by many households

4 = The morphotype similar to Jaluka but the petiole, leaf and corm contain poisons

* Protein content analyzed at Botany Division, NARC, Khumaltar, Lalitpur, Nepal.

The present diversity contains different value according to their plant parts, yield and specific traits for preparing special dishes. Farmers express that production areas allocated to individual varieties are determined according to their uses. Varieties that prepare a range of dishes are grown at larger scale and vice versa. The varieties that prepare specific dishes are widely grown by several households on a scale of a few plants.

6.3.7 Scientific evidence and farmers' perceptions about taro acridity

If eaten raw, parts of taro are acrid. Acridity irritates the mouth and throat. The cause is not clearly known. Two major explanations have been described; needle like calcium oxalate raphides (Sakai *et al*., 1972) and one or more 'chemical' irritants, possibly on the surface of the raphides (Tang and Sakai., 1983; Nixon, 1987). Through analysis two types of raphides (thick and thin) and druses (rosette like structure of calcium oxalate) were characterized in taro leaves. Acridity is due to double action of the sharp raphides in puncturing the skin and the irritant causing swelling and soreness (Bradbury and Nixon, 1998). The extent of acridity could be affected by soil factors. Changes in P level in the soil had no effect on taro acridity (Ma, Susan and Miyasaka, 1998). In acid soils aluminium may become toxic. Since taro-growing areas of mid and high hills are generally acidic, higher acidity combined with aluminium may be a stress factor affecting the exudation of acridity. The following section discusses farmers' perceptions of acridity and ways they deal with acrid traits.

Taro varieties are all acrid, but the quality of taro products depends largely upon the level of acridity. Acridity therefore has been one of the main selection parameters for variety selection. Emphasizing this, farmers state that "taro without acridity is equal to saying snakes without poison". Boiled corm or cormel is acrid when eaten warm. Vegetables if stirred while cooking are also acrid. To reduce acridity farmers adopt different treatments. A strong pickle of lemon, salt and chilly is necessarily used when consuming acrid items such as steamed leaf. Farmers viewed that acridity is variety specific and is influenced by the soil moisture regime. Accordingly, the higher the soil moisture the more the acridity it produces. Thus farmers categorically distinguished diversity with respect to acridity.

Of the 19 varieties, farmers were able to rank 11. Farmers said that the remaining eight local varieties were grown in their community but, they had never experience the taste. In terms of culinary quality, 'Panch mukhe' was the most preferred variety followed by 'Hattipow', 'Rato mukhe' and 'Lahure pindalu'. 'Thaune' and 'Chhaure' were the least preferred local varieties (Table 6.8). 'Dudhe karkalo' is almost free from acridity while 'Thaune' is rated as the most acrid.

Table: 6.8. Farmers' assessment of taro varieties against acridity, Kaski, Nepal (2001)

Variety name	Panel response	Farmers perception	Overall rating
Pancha mukhe	11	4.0	3
Hattipau	10	3.7	3
Khari	9	3.1	3
Rato mukhe	9	3.5	3
Raate	7	3.4	3
Chhaure	5	2.1	2
Kalo karkalo	5	3.0	3
Khujure seto	4	2.4	2
Dudhe karkalo	3	3.3	3
Lahure pindalu	2	3.5	3
Thaune	1	1.6	1

Note: 3 best.

Local varieties are classified and named based on local use values. Farmers distinguish diversity using a variety of descriptors of above and below ground parts. Local varieties of 'Karkalo' are recognized by their leaf shape and acridity. On the contrary, 'Pindalu' consists of local varieties known for their below ground parts. 'Pindalu' and 'Karkalo' produce high quality cormel even though they are known mainly for their petioles. 'Lahure pindalu', a variety known for its above-ground parts, for example, also produces high quality cormel. The high quality refers to best eating quality combined with low acridity. 'Jaluka' (grows in semi-aquatic condition) and 'Katch' (that irritates) are wild relatives with high acridity, and are eaten with certain treatments. Nepalese women farmers distinguish taro local varieties based on their acridity and know how to make best use of those varieties with high acridity.

6.3.8 Sensory evaluation of elaborated taro dishes

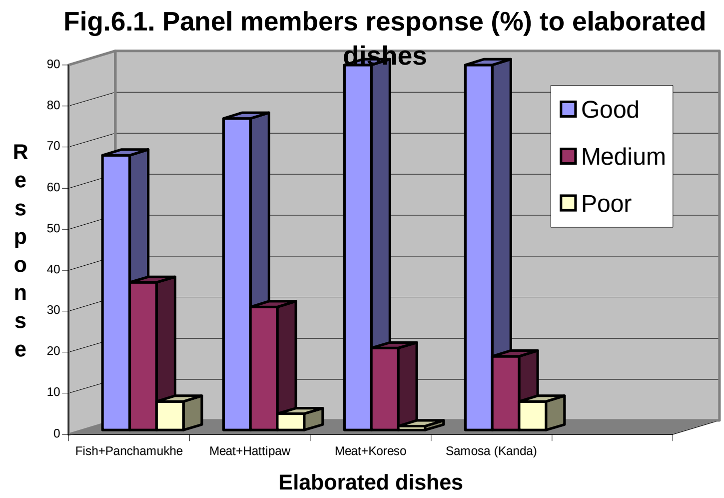
The panellists' responses on all the elaborated dishes are presented in Figure 6.2. All three panel groups unanimously rated 'Ujarka' to be the best-suited variety for the dish *Samosa.* Other preferred dishes were fish curry prepared with 'Panchamukhe' followed by dip fried mutton with 'Hattipow'. 'Panchamukhe' was largely preferred for curry dishes. Both farmers and housewives rated elaborated dishes similarly, except for fish curry with *Samosa* prepared from 'Hattipow', which farmers ranked after *Koresho* prepared from 'Hattipow' with mutton. Expert cooks and housewives liked *Samosa* most and *Koresho* mutton thereafter. Curry, when cooked with 'Tandre' and potatoes was least liked by farmers and housewives. Curry with peas and 'Hattipow' was liked by expert cooks. Farmers liked *Koresho* with peas, unlike the expert cooks and housewives (Table 6.9).

Table: 6.9 Sensory evaluation of elaborated food dishes revealed by three different panel groups, LI-BIRD (2002).

Panel group/Elaborated dishes	Expert cooks	Housewives	Farmers
1. Fish curry + Panchamukhe	4.4	4.2	3.9
2. Fish curry + Hattipow	4.0	4.3	3.7
3. Fried mutton + Hattipow	4.6	4.3	4.3
4. Curry peas + Panchamukhe	3.4	4.0	3.8
5. Curry peas + Hattipow	4.5	3.6	3.4
6. Curry peas + Koreso	3.3	3.8	3.8
7. Fried mutton + Koreso	4.6	4.7	4.6
8. Mutton curry + *Tandre* + Potato	3.5	3.5	3.3
8. *Samosa* (*Ujarka or Kanda*)	5.3	4.9	4.1

Note: Panel members given score x rating score for each good (5), medium (3) and poor (1) / total potential responses by consumer category.

The results show that all the panel groups preferred some dishes equally; 'Panchamukhe' with fish curry, 'Hattipow' with mutton and *Koresho* with mutton were popular dishes across the panel groups. Preference was also found to be panellist-group specific, e.g. the farmer panellists preferred mutton followed by fish and legumes thereafter. 'Panchamukhe' with curry dishes, 'Hattipow' with mutton and *Samosa* from 'Ujarka' were other preferred dishes.



Response: Total panellist x individual ranking as good (5), medium (3) and Poor (1) as above.

6.3.9 Increasing consumer demand enhances taro conservation

In response to the degree of use values, farmers expand or shrink the land area growing those particular local varieties. "Hattipow" was grown by many households in relatively large areas mainly because of its high yield (Chapter 5). This variety ranked average for all dishes items except for *Koreso*. The "Khujure", a low yielding variety was grown in large areas by many households for its preferred culinary character. Local varieties such as "Kalo karkalo", "Dudhe karkalo" and "Lahure" were still grown by many households for their specific uses, although over a decreased area. As shown in on earlier chapter, taro varieties with multiple uses are grown in large areas (30-250 m^2). "Hattipow" and "Khujure", cultivated by Kaski farmers, are examples of this.

There has already been one documented case where an *In situ* crop conservation project promoted recipes based on traditional varieties of taro, and concentrated on *Masaura*, the triangular nuggets that are extremely popular in cities and towns and are an excellent potential source of income. However, farmers found it difficult to meet the high demand for the product due to the limited supply of taro 'Jaluka', the acrid variety traditionally used for making *Masaura*. It was important that researchers worked closely with the farmers to evaluate different taro varieties to see which variety would function best as a substitute. 'Hattipow' was found to be the most popular alternative as it was easy to grow and yielded well despite its milder flavour. Networks were strengthened between growers, the producers of the *Masaura*, marketers and retail outlets so that farmers could sell their produce in a systematic manner. As a result of this effort, the area of 'Hattipow' planted in Kaski has increased.

Through discussions, three factors that constrain the promotion of local varieties have been identified:

1) Marketing systems
2) Lack of reliable supply of taro on a regular basis.
3) Lack of information on the requirements of urban consumers.

The extent and distribution of taro diversity are related to economic yield and local food values. It is important to understand end-use values of crops, as these determine the reason for maintenance of a particular variety with regard to conservation, protection and policy-making.

6.4 Discussion and conclusions

Local varieties with specific uses are maintained because certain dishes remain popular. Integration of such elaborated dishes derived from locally adapted and socially valued species in common cuisine may expand food markets. Taro dishes with mutton could be popular among urban consumers. The promotion of elaborated dishes may attract more consumers, which provide incentives to different parties including farmer-producers. Conservation of crop local varieties can thus be strengthened, provided the demand for their derived products is created or expanded.

The results from the experiment on the elaboration of taro dishes show that the preferences can be both common or vary between expert cooks, housewives and female farmers. It may, therefore, be unjust to generalise the preference trend based on the results of limited panellist responses. This information however, gives a basis for the selection of some elaborated dishes for purpose of promotion.

Certain local varieties were preferred for some dishes with other multiple uses. In Kaski, “Dudhe karkalo” is known for pickles, leaves and young shoots. “Panchamukhe” and “Khujure”, both cormel types, are preferred for dishes prepared from leaves and shoots. As discussed in chapter 5, varietal diversity corresponds to the richness in food items. However, this is not always so. Jumla and Bara farmers prepare about six dishes from a single variety. In Kaski, at least 13 different dishes are prepared where more than 16 local varieties are grown. In all villages, fresh leaves, shoots and cormels were identified as common items. The study revealed that the majority of dishes are common dishes but a few are location specific. Matthews (2004) in his review found inadequate evidence to draw correlations between culinary knowledge and genetic diversity. From the review he noted that taro genetic diversity has been decreasing in areas with long history of cultivation (e.g. China and Japan) because taros were grown at larger scales with some selected local varieties. However, the extent and distribution of taro diversity to recently introduced areas such as New Zealand has been increasing (Matthews, 2004).

Farmers and their households prefer certain taro local varieties to others depending on their favourite recipes, which in turn affects the extent of taro diversity found in their gardens. Local women prepare several dishes from taro and have devised a number of techniques for reducing acridity in many of these dishes. For example, they add lemon, salt and chilli to steamed leaves. Some recipes are selected specifically for more acrid taro varieties, because they give the dish a stronger flavour. For example, 'Jaluka' is particularly acrid and is the most popular variety for preparing *Masaura*, traditional triangular nuggets made from taro leaf stalks (petioles) and black gram flour.

A major factor determining the number of varieties planted is the number of ways they can be cooked. Varieties that can be used in many different dishes were grown on a larger scale than varieties used for only one purpose. For example, 'Khujure' which was used in soups and in curries, was grown on a larger scale, as were 'Hattipow' and 'Panchmukhe' since all parts of the plant can be used. 'Gante', on the other hand, used mainly to make *Khasaura*, is a much rarer variety.

In Kaski, the richness of local dishes correlated positively with varietal diversity. In other villages, multiple dishes are prepared from a single variety suggesting that the use values differ between local varieties. Local varieties which are correlated with local dishes are likely to continue to grow because demands for their derived products have either been consistent and or increased. Farmers have categorically identified local varieties suitable for particular dish or dishes. It is evident that farmers have also identified some substitute local varieties. In addition, the sets of local varieties with special uses can be introduced to new areas where farmers' options are limited. Since taro is not predominantly grown for sale on a large scale, one way to promote the conservation of taro local varieties might be to increase their value by increasing their profile through marketing different dishes, such that it becomes more attractive commercially. This would enable local people to earn additional income, which in turn will increase their use and conservation of taro varieties.

Food traditions are an important subset of the peoples' livelihoods. Crop local varieties that are linked to those food traditions are also being displaced due to a growing popularity of the modern varieties. The overall effect of this is that farmers are being discouraged from growing local varieties. This is true of rice in India where no remuneration is offered to farmers for maintaining agro-biodiversity. Financial incentives are offered, however, to farmers who plant modern, high-yielding varieties (Prakash and Virchow, 2003). Thus, the marketing of traditional varieties could have the added effect of creating incentives to continue growing crop local varieties for their derived products. Taro is a difficult crop to export in its fresh state; the corm is the main part of the plant used on a global scale, and it bruises easily (Onwueme, 1999). It also is bulky and has a short shelf life of a few days when stored at ambient temperatures. In Hawaii the processed forms of taro are produced in rural cottage industries thereby creating the need for facilities such as sorting, cleaning and packing. Here, the processed taro industry provides an avenue for poverty alleviation and employment generation in rural areas. Implementing this model in Nepal, through the creation of elaborated food items using taro local varieties, would lead to the consequent conservation of taro diversity as well as employment generation and the valuing of local varieties. Thus, local uses and taro diversity are positively related.

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[i] Secondary meals are dishes served along with primary meals.

CHAPTER 7: LOCAL NAMES DISTINGUISH RICE DIVERSITY

In this chapter, research results are presented regarding the amount and distribution of rice diversity, and ways farmers name and distinguish rice diversity. It is examined how local knowledge corresponds to scientific descriptions. Farmers' bases for naming varieties, ecosystems and soils are compared with the scientific literature. Policy implications of the key research findings on the management of rice diversity on-farm are discussed.

7.1 Introduction

Rana (2004) studied food and socio-cultural traditions related to rice landraces in Nepal. The study stressed that rice landraces have been grown for different local use and adaptive values. Farmers' knowledge about distinctive use values, their requirements for variable social, ceremonial, cultural and religious occasions is documented. The same study documented the number of rice varieties grown in different ecosystems for both study areas. In addition, the main festivals and ceremonies that require special food recipes prepared from rice landraces are described. The author also elaborated farmers' perceptions with respect to landraces' medicinal values and the concept of 'variety purity' and their roles in variety maintenance on farm. However, the study failed to document farmers' perceptions regarding the ways rice landraces are affected by environment factors when grown away from their traditional habitats. Local ecological and botanical knowledge behind farmers' management of crop diversity is poorly known.

Bajracharya (2003) assessed diversity of farmer-named varieties of rice and farmers' consistency in distinguishing this diversity from Jumla, Kaski and Bara sites. In terms of local names, a great number of varieties was recorded for Kaski and Bara but fewer at Jumla. Cluster analyses were performed on agro-morphological data of farmer-named varieties from all three sites in order to assess the distinctiveness in terms of their agro-morphological characters. At the two lower elevation sites identically named landrace populations clustered together, showing a high degree of consistency in names with agro-morphological descriptions whereas at the high elevation, although there was a diversity of names, little morphological diversity was found for measured traits (Bajracharya, 2003; Bajracharya *et al*., 2004).

The study showed that a larger number of landraces are grown across two moisture regimes followed by those grown in one regime and a few landraces grown across the three moisture regimes. Morphological studies revealed that landrace diversity was higher in Kaski and Bara while it was minimal at Jumla. The marker assisted analysis showed a similar trend among landrace populations as agro-morphological characterisation data, higher in Kaski and Bara and low among landrace populations from Jumla. The study shows that Bara and Kaski farmers name their varieties consistently while Jumla farmers were inconsistent.

This section contains a discussion on the factors that influence farmers' naming systems. Nepali farmers are consistent in their identification of diversity, with names reflecting distinct varietal characteristics. It is reasonable to assume that the diversity of named varieties reflects genetic diversity. Molecular analysis has confirmed the assumed correlation of varietal and genetic diversity on taro in China (Dongxiao and Guman, 1998). Since past studies explored knowledge associated with the ecosystem's individual components, knowledge generated by interaction between ecosystem and genotypes has been limited. This study here focuses on how farmers distinguish diversity locally and examine whether 'names' *per se* appropriately approximate diversity. If farmers are consistent in naming their varieties the likelihood is that 'farmer given names' can be reliably used to estimate diversity. In this research the following key questions are explored: a) how do farmers distinguish rice varieties; b) how do farmers describe traits for specific environments or generally; and c) are farmers consistent in describing crop diversity?

Questions not addressed by earlier research are - do farmers use 'name' as a unit in distinguishing diversity? Does name *per se* indicate adaptive and or use values? This study explores the literal meaning of names with particular focus on adaptation. It was also examined whether names *per se* indicate local uses and distinct values. This research is a part of a larger project in which two other scholars carried out detailed studies on landrace diversity and its use values. This study therefore focuses on farmers' systems of naming landraces in relation to ecological adaptation.

7.2 Research methods

7.2.1 Household surveys

Individual farms were classified according to their predominant rice ecosystem by the local description (see Tables 7.1 and 7.2 for details). The most common ecosystems, three in Kaski and two in Bara, were selected. A total of 550 households were registered in these study areas. From each of those five ecosystems a random sample of 35 households was drawn. Thus, a total of 175 households were included in the survey. The survey addressed questions about rice environments and rice diversity. Farmers were interviewed about their perceptions of adaptive traits, local adaptation and the effects of local practices, soil moisture, soil texture and external inputs on rice diversity.

7.2.2 Focus group discussion

To gather collective responses or differences on matters relating to people's perceptions, experiences and opinions, focus group discussions (FGD) were conducted. Further details can be found in chapter 2. For each FGD some 9 to 11 active and knowledgeable farmers belonging to the same gender and wealth categories were invited. Four FGD were organized: two each at Kaski and Bara.

7.2.3 Data analysis

Descriptive statistics and the analysis of variance were performed on the survey data. Farmers' responses were converted into a relative preference ranking as described in Chapter 6:

$$\text{Preference ranking} = \sum_{i=1}^{n=N} \frac{5 \text{ x n} + 3 \text{ x n} + 1 \text{ x n}}{\text{N}}$$

Greater mean value indicates positive associations. Similarly, the diversity was estimated using Shannon index (Shannon and Weaner, 1949).

$$H' = -\sum_{i=1}^{n} Pi \ln(Pi)$$

Where,

P_i= Proportion of total number of individuals that are of species *i*

H'= Shannon-Weaner Index of Diversity

7.3 Results

7.3.1 Locally named rice diversity

If farmers distinguish varieties by names created according to distinct characteristics, then names *per se* should, reliably approximate to diversity. In both study areas, farmers distinguish diversity by name(s) created after traits linked to adaptation and uses. A secondary name is appended to distinguish populations when grown under different environments. The landraces Jarneli and Jhinuwa, for example, are distinguished based on the environments where they can be grown (Table 7.1). In such cases, the primary name describes visible variety characteristics while the secondary name indicates the environments where they can be grown. Diversity is distinguished also by the origin, which could be a place or an institution. The variety introduced from *Madhesh* (*Tarai* plain) is called Madheshe; Janaki is used for varieties that come from *Janakpur* area; and Mansara is called so because it probably came from around the Mansarobar Lake of Western Nepal. Thus, the names provide a historical perspective of variety origin (Table 7.1). Nepali farmers use plant names that reflect a broad spectrum of local knowledge about the plants' habitats, forms, similarities to other plants, uses and other attributes (Manandhar, 2002).

Table 7.1 Local names, literal meanings of farmers' varieties of rice at Kaski site, Nepal.

Primary name	Secondary name	Literal meaning	Translation
1. Aanadi		Anna doshi	'Impure' & not acceptable in socio-religious ceremony
	1.1 Rato	Rato rang	Red grain colour
	1.2 Seto	Seto rang	White grain colour
2. Basmati		Basna aaune	Aromatic
3. Ekle		Ek ek biruwa ropne	Transplanted single seedling per hill
4. Ghaiya	4.1 Ghaiya	Ghar barima lagaune	Grown around homestead area
	4.2 Gajale	Dana ma gajal lagaya jasto	Husk looks like *gajal* (black color) lined as eyelids
	4.3 Jiri	Jira jastai masino	Grain size that of cumin seed
	4.4 Jhyale	Patalo/chhidro phalne	Sparse grain setting
	4.5 Masuli	Mansuli ko dana jasto	Like grains of a referee variety
	4.6 Rato	Rato rangko dana	Red grain husk colour
	4.7 Seto	Seto rangko dana	White grain husk colour
5. Gudura	Gudura	Gola, batula dana	Round shaped grain
6. Gurdi	6.1 Gurdi	Ghurmailo dana ko rang waa Gure rang	Whitish brown grain husk colour
	6.2 Kathe	Pakho/rekho athawa kathma ropne	That is cultivated in marginal slopping lands
	6.3 Lahare	Balama lahara lahara bhayara phalne	Clustered panicles
	6.4 Sano	Sano bot hune	Short plant height
	6.5 Thulo	Dana thulo bhayakole	Bold grain size
7. Janaki		Janakpur anchal ma bikash bhayako?	Probably developed in Janakpur, a place in Nepal *Tarai*
8. Jarneli	8.1 Jarneli	Dhan ra paral jarro	Rough grain and straw
	8.2 Dhave	Dhavma lagaine	Grown in Dhav
	8.3 Pakhe	Pakhama ropne	Grown in uplands
	8.4 Pani	Pani badhi hune jaggama lagaune	Grown in water abundent areas
9. Jetho budho		Dhan bharima jetho (uttam)	Best of all rices
10. Jhinuwa	10.1 Jhinuwa	Jhinu / masino dana, bot	Small grain and weak plants
	10.2 Ghaiya	Gharbarima chharne	Sown around homestead areas
	10.3 Dhave	Dhav ma hune	Grown in Dhav
	10.4 Kalo	Danako rang kalo	Black grain colour
	10.5 Kanajira	Jira jasto sarhai sano	Smallest grain as that of cumin seed
	10.6 Pakhe	Pakhama ropne	Grown on sloping lands
	10.7 Seto	Danako rang seto	White grain colour
11. Madeshe		Madhesh bata lyayako	Introduced from the plain *Tarai* (Madesh)
12. Mansara		Mansarobar tal bata lyayako	Introduced from Mansarobar Lake of western Nepal
13. Nepte		Danako tuppama bangiyako	Slightly bended tip of the grain
14. Pahele		Dana pahenlo rangko	Yellow grain husk colour
15. Pakhe ramani		Pakhama lagaune ramro dhan	Good quality rice grown on sloping lands
16. Raate		Dhanko bahiri rang rato	Red grain husk colour
17. Ramsali		Dhan maddhyeko chhokho bhayakole bhagawanko nambata rakheko nam	Purest among rice varieties and named after the god
18. Ramani		Ramro dekhine (sun jasto ramro dekhine)	Attractive looking like gold
19. Tunde		Danako Tuppama tudo bhayakole	Typically awned

Source: Focus Group Discussion with Key Informants, Kaski and Bara, Nepal

Farmers who speak different languages still employ similar naming systems although there are some differences. The improved or introduced varieties are identified by the same name if they are easier to remember or by nicknames if most traits resemble to that of already known varieties. In some instances, the introduced varieties are nicknamed after some widely grown varieties with similar characteristics. Bara farmers call an introduced variety ‘Masula’ because it has agronomic characteristics similar to that of an improved variety ‘Masuli’.

Farmers also distinguish landrace populations according to distinct morphological traits, such as grain color and plant height. Names used for externally introduced varieties are usually unchanged and without any known meaning associated with them (Table 7.2).

Table 7.2 Local names, literal meanings and translations of farmers' varieties of rice studied with Bara farmers of Nepal

Farmers' named varieties	Literal meaning and translation
Anadi	'Relax' people relax / enjoy while eating Anadi products such as puffed rice.
Basmati	Bas=Aroma (bashna aaune)
Botuwa	Indian name (variety imported from bordering to India, meaning not known)
Farm*	Variety introduced from research station/farm.
Jiri	Jiri=small grain size, the shape and size to that of cumin seed
Kanchhi masuli	Kanchi=small sized grain, variety with the smallest sized grain grown in the area
Manika	Variety introduced from India, meaning not known.
Masula*	Masula=Characteristically looks like Masuli
Mutmur	Mutmur=transplant quickly (jhatpat garera ropnu parne dhan), sensitive to age of seedling.
Natawa	Nat=Dwarf, plants with short height
Natmasula	Nat=dwarf, Masula=Grain colour like Masuli, widely grown improved variety
Pankaj*	Variety introduced from India, not known.
Phillips*	Variety imported from of India, meaning not known.
Saro	Saro =Bhadaiya, variety matures during the month of Bhadra as per Nepali calendar i.e. August-September
Sathi	Matures sixty days after transplanting
Sokan	Shakti bardhak, gives quick energy, served especiallyto ill and sick people.
Sona masuli*	Sona=Seeds with golden husk cover
Ujarka masula	Ujarka=white husk cover, masula= Grain colour of the same as Masuli

Source: Focus Group Discussion with Key Informants, Kaski and Bara, Nepal

An extensive study of rice names was made in the Laos PDR. A collection of 13,192 samples of cultivated rice compiled between 1995 and 2000 (Rao *et al.*, 2002a) was followed up by a systematic study of names and naming systems (Rao *et al.*, 2002b), in which 3169 distinct variety names were recorded. A three-layer naming system consisting of a basic name, a root name and a descriptor was found. The names reflect the production ecosystem, endosperm type, and maturity date. This naming system clearly resembles the one found in Nepal that reflects exact knowledge about varietal suitability under the diversity of local production environments, quality traits that are important in local food culture, and agronomic and morphological traits that are used to identify the varieties.

7.3.2 Distribution of rice diversity

Forty-one farmers' varieties were found in Kaski and 15 in Bara. The mid hills, which are less affected by technological interventions such as irrigation, fertilizer supply, and access to roads and markets, have retained more of the traditional varieties than the lowlands. Kaski farmers grow one or two modern varieties each and a larger number of landraces (1-11), regardless of moisture regime (Table 7.3). In Bara, the situation was the opposite, with a relatively high number of modern varieties and few landraces across farm ecosystems. However, landraces, albeit few in number, were present on each visited farm.

Table 7.3 Extent and distribution of rice diversity recorded in Kaski (Households = 135) and Bara (Households = 70), Nepal.

Study areas	Moisture regimes		No. of cultivars per HH		No. of cultivars (range)		H'
	Local name	English	Improved	Landrace	Improved	Landrace	
Kaski	'Ghaiya'	Upland	1.2 ± 0.17(6)	6.6 ± 0.39(35)	1-2	1-11	1.0
	'Tari'	Rain fed	1.1 ± 0.11(9)	5.9 ± 0.26(75)	1-2	1-11	0.8
	'Sinchit'	Irrigated	1.3 ± 0.11(19)	5.6 ± 0.23(89)	1-2	1-11	2.5
	Dhav	Swamp	1.3 ± 0.14(12)	5.6 ± 0.39(40)	1-2	1-11	2.2
Bara	'Ucha'	Rainfed	2.7 ± 0.14(66)	1.1 ± 0.05(22)	1-6	1-2	1.3
	'Nicha'	Irrigated	3.1 ± 0.15(51)	1.1 ± 0.05(22)	1-6	1-2	1.4
	Samatal	Rainfed	2.3 ± 0.19(27)	1.0 ± 0(8)	1-4	1-1	1.1
	Maan	Swamp	3.5 ± 0.5(2)	1.0 ± 0(1)	3-4	1-1	na

Household survey (2002), Number in parenthesis indicates varieties in the system, na: not analyzed.

7.3.3 Rice diversity and preferred traits

Farmers have identified several factors that structure crop diversity. Studies show a variable distribution of farmer-named varieties across agro-ecological zones and ecosystems within the individual zones. Greater cultivar diversity was recorded in the mid hills compared to the *Tarai* plain. As described for individual study areas earlier, variable distribution was associated with farmers' access to agricultural inputs, extension, and market services. Distribution of diversity was related to the existing soil moisture, soil nutrients and soil texture. Compared to rain fed and upland fields, more rice diversity was recorded in irrigated ecosystems where both improved varieties and landraces are grown. Locally, ecosystems are selected to suit varieties available to farmers. Rice varieties that have fine grain and high quality are grown under favourable environments, while those with coarse grain and that are non-aromatic are grown under upland or rain fed fields.

Farmers distinguish diversity using locally identifiable descriptors. Farmers recalled as many as 27 such descriptors that distinguish diversity. Most descriptors were related to grain yield, local adaptation, grain quality, and morphological and phenological characteristics. Farmers put more emphasis on descriptors that relate to local adaptation, followed by grain yield, and characteristics that determine market value. Farmers' descriptors varied over agro ecosystems and individual ecosystems (Figure 7.1).

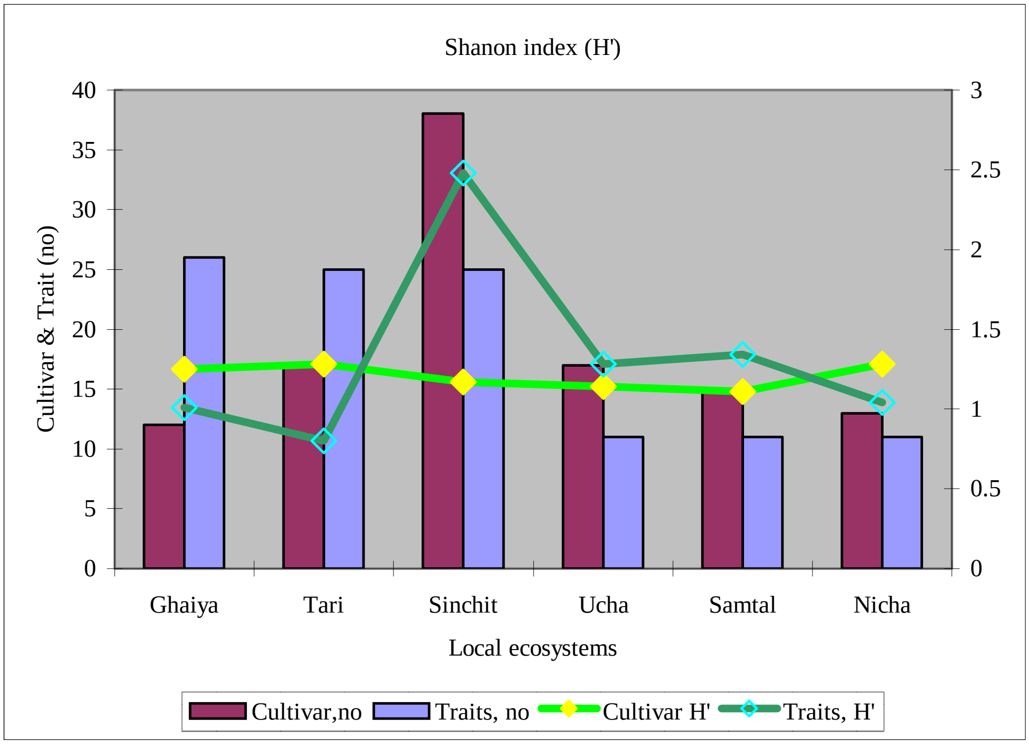


Figure 7.1 Farmers distinguished rice diversity across ecosystems using local descriptors in Kaski and Bara, Nepal

7.4 Discussion and conclusions

Farmers distinguish diversity through local names created after the variety *per se* and environments in which they were grown. Names are created locally according to the a) cultivar specific trait(s); b) the place from where a particular cultivar comes; c) association with socio-cultural values; and d) cultivars that grow in specific seasons. Farmers use the same name, especially for improved or exotic cultivars, and particularly when their names do not represent cultivar-specific traits. Cultivars are also distinguished by nicknames and or secondary names. On both sites, farmers named varieties in a similar manner although they spoke different languages. This research showed that farmers name varieties based on distinct traits associated with a particular variety. Farmers' bases of naming varieties are also related to adaptive traits. At the same time, other distinct traits were referred while naming varieties.

Bajracharya (2004) reported that high hill rice farmers of Nepal were particularly inconsistent in naming varieties. There could be several interpretations on why farmers are inconsistent in naming varieties especially those cultivating rice in stressed environments (e.g. upland, rain fed). As discussed in chapter 6, high hill farmers might have observed changes on their populations when the same named variety was grown under varying ecosystems. The reciprocal transplant experiment conducted across moisture regimes (Chapter 10) revealed that the performance of different landrace populations was affected by ecosystem factors. It is therefore possible that farmers observed distinct traits when the same population are grown under variable environment.

The maintenance of diversity and farmers' preference differs according to the resource endowments of the farmer. Farmers maintain a greater number of varieties in more favourable environments such as irrigated ecosystem and vice versa. Unlike farmers' cultivating rice under favourable environments at larger scale, the subsistence farmers consider greater number of preferred traits while selecting varieties (Figure 7.1). Compared to the *Tarai* plain, the mid hill farmers consider varieties only when they contain adaptive traits. *Tarai* farmers are more concerned with grain yield and attributes that determine grain yield. Unlike mid hill farmers they disregard varieties for threshing characteristics where threshing is performed by bullocks or machines.

Local names can be reliably used to distinguish as well as measure rice diversity better when names reflect distinctive traits. Such names provide additional information related to the growing environments, specific uses and their movement. Understanding farmers’ reasons for the maintenance of rice diversity and associated knowledge provides a foundation for effective research and development strategies, appropriate for ecosystems or ecological niches within the individual agro-ecological zones.

CHAPTER 8: FACTORS SHAPING PLANT ADAPTEDNESS

This chapter discusses i) factors that affect crop diversity, ii) farmers' perceptions of plant adaptations and iii) the ways adaptations are assessed locally. Farmers' perceptions of adaptation with particular reference to taro and rice are presented. The ways farmers and researchers describe adaptations are discussed. The research results are compared with related previous study findings.

8.1 Introduction

The complexities of ecological conditions to which rice is adapted, specially the breadth of hydrological conditions, indicate that great variability for water-related adaptation exists within the germplasm. When a water deficit occurs for either upland or lowland rice, the competitive advantage appears to shift toward the weed species (Toole and Chang, 1979). Plant response can differ for ecosystem factors than that of individual environment factors. In conventional research plant performance is often related to individual factors. In actuality plant performance could have been affected by a number of ecosystem factors. The degree of influence of individual or combined factors on plant adaptation varies with ecosystem. The mode of response and the feature of rice-based ecosystems are presented (Table 8.1).

Table 8.1 General descriptions of environmental factors potentially interacting with a rainfall deficit conditions to create an array of complexes collectively referred to as "drought"

Variability	**Factor**	**Cultural systems**		
Edaphic		Upland	Lowland	Deep water
	Soil depth (root horizon)	Often deep	10-30cm	Usually deep
	Soil texture	Sandy to clay loam	Clays and a few loams	Clays
	Physical hard pan	Uncommon	Present	Absent
	Hydraulic conductivity	High	Low	Low
	Chemical/biochemical	Aerobic	Anaerobic	Aerobic-anaerobic
	Deficiencies or toxicities			
	Fe deficiency	Yes	No	No
	Zn deficiency	No	Yes	Yes
	Al toxicity	Yes	No	No
	Native fertility	Low	Wide range	High
Climatic	Rainfall (crop season)	500- 1500m	700-2000mm	Not relevant, influx is from surface flow
	Distribution	3-4 months > 200mm	3-7months> 200mm	Deficits in early stage associated with erratic onset of monsoon
	Temperature (air and soil)	Variable by geographic location-longitude, latitude, elevation-hydrological conditions		
	Atmospheric evaporation demand	Determined primarily by macroclimatic conditions but respond significantly to microclimatic modifiers		
	Solar radiation during crop season	Generalization on quantity or photoperiod not possible		
Hydrologic	Water depth (surface)	Rarely >0cm	0-50cm	1-6m
	Water depth (subsurface)	Low	High often perched	Positive
	Flood	Rare	Rare to annual flooding	Annually
Biotic	Competitive	Severe	May be severe	Serve during establishment
	Plants (Weeds)	Drought accentuates the problem in all systems…		
Agronomic	Land preparation	Dry	Wet	Dry
	Crop establishment	Direct sown	Direct sown or transplanted	Direct sown (Dry)
	Use of agri-inputs	Negligible	Wide range related to water control	Negligible

Source: Toole, J. C; and T. T, Chang (1979), ed. Harry Mussel and Richard, C Staples, Stress Physiology in Crop Plants, John Willey and Sons, New York.

8.2 Abiotic factors and plant adaptation

Climatic adaptation of plants involves both the genetic adaptation of the populations and the ability of individuals to buffer environmental changes through modifying their phenotypic response (Matyas, 1997). Genetic adaptation is understood as a change in gene frequency, directed toward a theoretical optimum in any given ecological situation. The effects of toxic elements can be significant and even influence the physiology of crops. Nutrients can cause toxicity if in over supply. Depending upon the nature of crops, their requirement as well as the tolerance limit can be different. Some species are responsive to certain ecosystem factors whereas other species respond to others.

In taro, chlorosis of leaf blades and abnormal root morphology was observed with Fe deficiency. There was a positive relationship between the size of leaf blade, dry matter yield and leaf blade Fe content (Ares, *et al*., 1996). Likewise, the application of nitrogenous fertiliser in split doses improved use efficiency but did not improve corm yield (Ramnanan, *et al*., 1995). Plants grown in the shade had more petiole and lamina growth and extension as well as inverse tip:corm or tip:cormel ratios. Shade plants had a higher leaf area index than sun grown plants (Valenzuela *et al*., 1991). Taro had longer leaves and more chlorophyll and carotinoides per plant, especially when grown under shade. Compared to sweet potatoes and cassava, taro appeared to be more tolerant to shade (Johnston and Onwueme, 1998).

8.3 Biotic factors and plant adaptation

Scientific literature often elaborates plant adaptations categorically according to specific environmental factors. So the scientific literature interprets plant adaptability against those environmental factors. The knowledge derived from such studies could be different from those that look at complex environments found under traditional ecosystems. It is the farmers who hold knowledge of their crops, environments and the knowledge derived from interactions between crop diversity and environment. Understanding the scientific basis of local knowledge is important for the present and future use. The specific questions addressed are

i) how do farmers interpret adaptation in crop plants,

ii) how do farmers assess adaptation on taro and rice varieties?,

iii) what parameters are used to assess variety adaptation on taro and rice?,

iv) to what extent farmers and scientific literature agree in interpreting adaptation.

Because of the inadequacy of scientific research on crop adaptation and adaptability, additional research on farmers' knowledge and understanding of adaptation is needed. The following sections elaborate research methods used to study farmers' perceptions about adaptation and adaptability of crop diversity, including environmental factors.

8.4 Methods

8.4.1 Focus group discussion

Focus group discussions were conducted to gather group response, perceptions, experiences and opinions. To make the discussions more effective, only participants of the same wealth category were invited. Key informants were also selected based on their knowledge of earlier reports related to social and natural resources mapping and farmers' network analysis (Subedi *et al.*, 2002). Along with nodal farmers, diversity-minded male and female farmers were invited. Discussions were organized in order to a) identify farmers possessing more ecological knowledge; b) assess the distribution of crop ecosystems and niches; c) investigate crop diversity; and d) learn how farmers distinguish soils, ecosystems and taro diversity.

8.4.2 Household surveys

In both study areas, not every household grows taro on-farm. In both study areas, 35 randomly selected taro farmers were interviewed. The key areas included cropping system, adaptive traits, and adaptation. Farmers' perceptions of the relationship between cultivation practices and economic traits were collected. Their responses regarding the effects of ecosystem factors on product qualities were recorded.

For rice, individual farms were classified according to the predominant rice ecosystem by the local description. The most common systems, three in Kaski and two in Bara, were selected. A total of 550 households were registered in the study areas. From each of those five ecosystems a random sample of 35 households was drawn. Thus, a total of 175 households were included. The survey addressed questions about rice environments and rice diversity. Farmers were also interviewed about their perceptions of the effects of adaptive traits, local adaptation, effects of local practices, soil moisture, soil texture and external inputs on rice diversity.

8.4.3 Data analysis

The estimated weighted mean for individual parameters was analyzed statistically. Descriptive statistics and the analysis of variance were performed on the survey data. Farmers' responses were converted into a relative weighted mean before performing the statistical analysis. The relative weighted mean was estimated as follows: number of responses (n) x 5 (if rated effects are positive or good) + (n) x 3 (if rated effects are positive or medium) + (n) x 1 (if effects are low or poor) divided by the total number of respondents (N):

Preference ranking = $\sum_{i=1}^{n=N} \frac{5 \text{ x } n + 3 \text{ x } n + 1 \text{ x } n}{N}$

8.5 Results

8.5.1 Farmers' assessment of local adaptation

Farmers describe adaptation in different ways. Crop varieties successfully grown under local conditions are considered as *lageko*[1]. In other words, varieties are considered adapted when they 'grow well' under changed environments. The performance of introduced varieties is compared with varieties already established in that area. Farmers listed several parameters through which cultivar adaptations are defined and performance assessed (Table 8.2). Farmers defined adaptation using as many as 20 descriptors, but, this number varied across study areas. Kaski farmers used a total of 17 descriptors. To assess cultivar adaptation farmers refer cultivars' performances grown in their traditional habitat. If the performance of individual trait(s) differs from their traditional habitat, then farmers further examine whether these alterations are positive or negative. In most instances, cultivars are considered adapted when their performance remains the same or improves against those grown under traditional habitat. Farmers are mainly concerned with the performance of individual traits that have economic importance.

8.5.2 Performance of individual traits measures adaptation

Bara farmers describe and measure taro adaptation in terms of tuber yield, acridity, infestation of diseases and pests, and the shoot count. Root growth and colour are also observed. Most farmers in Kaski and all farmers in Bara regarded larger yield and less acridity as key traits. Plant height and culinary characters were other preferred traits (Table

[1] Farmers collectively called local adaptation *lageko*, often referring to the suitability of their soils and climate.

8.2). For Bara farmers, cultivars are considered adapted (*lageko*) when their performance remains the 'same' or 'improves' when grown under changed environments.

Table 8.2 Descriptors mentioned by farmers for measuring adaptation in Kaski (HH=35) and Bara (HH=35), 2002.

Farmers' descriptors	No. of farming households			Weighted mean	Farmers' descriptors	No. of farming households			Weighted mean
	Kaski	Bara	Total	%		Kaski	Bara	Total	%
Relative yield	25	35	60	15.5	Corm size	12	0	12	3.1
Acridity	19	35	54	14.0	Plant health	10	1	11	2.8
Plant height	18	18	36	9.3	Plant growth	10	0	10	2.6
Pest attack	11	18	29	7.5	Root growth	0	9	9	2.3
Taste	5	21	26	6.7	Petiole size	8	0	8	2.1
Plant senescence	20	0	20	5.2	Eating qualities	7	0	7	1.8
Plant color	13	7	20	5.2	Leaf size	7	0	7	1.8
Cormel count	17	0	17	4.4	Petiole shape	7	0	7	1.8
No. shoots	0	17	17	4.4	Uniformity	0	6	6	1.6
Corm shape	12	5	17	4.4	Number of descriptors	17	11	20	
Leaf senescence	13	0	13	3.4	**Shannon Index**	**1.24**	**0.78**	**1.26**	**NA**

Source: Household survey, 2002; Weighted value = total responses divided by the total no. of responses, expressed in percentage.

Farmers consider taro as a 'variety' only when it 'grows well' under local conditions. Farmers listed specific descriptors for assessing adaptation. One farmer described adaptation in terms of 'maturity duration'. Introduced varieties that mature at the same time or earlier than local varieties, are considered adapted. The most responsive traits farmers consider include acridity, plant height, disease and pest infestation and leaf senescence.

The Shannon Index for farmers' descriptors was higher for Kaski (H'=1.24) than for Bara (H'=0.78). The number of farmers' descriptors and varieties seem to be related. This reflects farmers' preferences that vary by socio-economic and environmental conditions. Farmer-identified descriptors common to both study areas (n=8), Kaski specific (n=8) or Bara specific (n=3). Bara farmers recounted a considerable number of descriptors through which adaptations are described and measured.

8.5.3 Ecosystem factors and agronomic traits

During the field survey farmers recalled 24 different traits which are directly affected by ecosystem factors (Table 8.3). They stated that environmental effects could be determined by direct visual observation of shape, size and number of corms, cormels, leaf blades and petioles. Farmers sometimes observe leaf colour and the acridity of leaf, cormel or corm. The size of corms and cormels, number of cormels, and leaf size may be affected when cultivars from open fields are grown in intercropped systems. The plant height and petiole thickness increase under intercropping. Some farmers said that leaf colour turns darker green, but a few farmers said that plant colour does not change. It was the farmers' perception that the performance of certain traits could be improved when cultivars are grown away from their traditional habitat, especially corm size and shape, leaf colour, number and size of the petioles, taste and acridity. Farmers also opined that infestation of foliar diseases increases when varieties adapted to mono-culture were cultivated under intercropping. Farmers had different experience with home garden cultivars when grown under mono-cropping. The size of corms, petioles and cormels increase, taste and acridity could sometimes be improved, and the incidence of disease could be reduced (Table 8.3).

Table 8.3 Farmers' opinions on what might happen if cultivars were to be introduced to a different crop system: a survey of 35 households each at Kaski and Bara, Nepal.

Plant response	Opinion - if cultivars were introduced			
	In Kaski		In Bara	
	from mono to mixed crop	From HG to mono crop	from mono to mixed crop	From HG to mono-crop
Attractive corm	1	5	-	-
Attractive/greener	-	8	-	
Large size corm	-	10	-	-
Large size cormel	-	9	-	2
Large size petiole	-	13	-	-
Lower no. cormel	8	2	-	1
Higher no. cormel	-	7	-	-
Mottle leaf blade	3	3		-
Small corm size	20	7	2	-
Small cormel size	11	6	-	-
Small leaf size	10	4	-	-
Decrease acridity	-	3	-	1
Greener leaves	1	3	-	-
High disease	6	1	7	6
Low disease	-		6	7
Improved taste	1	3	-	-
Low yield	3	4	7	13
Improved yield	-	-	12	5
Many shoots	-	3	-	-
Medium height	-	11	-	-
Short height	4	-		2
Small petiole size	10	12		
Tall height	5	3	4	
Good taste		-	6	8

HG=Home Garden, - = not reported

Bara farmers reported that environmental effects might be seen in 18 different characteristics of economic importance when cultivars are grown away from their traditional habitats. The effects could be seen on corm size and yield, taste and acridity, and shoot counts. Kaski farmers experienced that yield, disease incidence, plant height and shoot emergence would improve when cultivars grown with mono-cropping were cultivated under intercropping. Some farmers said that corm size could be negatively affected. Farmers stated that tuber yield decreases when cultivars grown under mixed cropping were cultivated under mono-cropping.

Some farmers explained that tuber yield increases in the open field because of improved access to sunlight. This shows that farmers have clear idea of adaptation and adaptive traits.

8.5.4 Local practices and performance of varieties

In the mid hill areas, taros are planted in irregular dibbles (≈ randomly) made with a spade and are supplied with organic fertilisers. The plots are mulched with locally available materials such as forest litter. On the *Tarai* plain, taros are planted in deep furrows with inorganic fertilisers and frequent irrigation. Analysis of farmers' responses revealed no significant effects on product qualities ($p<0.01$) from low moisture, clay-like soil texture or low-external inputs. Farmers' perceptions regarding effects on traits were found to be similar across study areas (Table 8.4).

Table 8.4 Weighted mean estimated against farmers' response on associations between ecosystem factors and key traits, Kaski (HH=35) and Bara (HH=35), 2002.

Descriptor	Local practices								
	Planting method			Moisture level		Soil texture		External inputs	
	Flat	Furrow	Mulch	Excess	Stress	Clay	Sandy	Low	High
Kaski									
Acridity	4.6	2.0	1.0	2.5	7.2	11.3	3.7	3.0	NA
Corm shape	3.3	9.5	18.0	10.4	12.5	10.4	8.0	6.0	NA
Cormel size	3.5	8.0	17.0	9.0	11.8	10.2	7.5	5.0	NA
Taste	4.7	3.0	2.0	4.8	13.1	9.5	7.0	7.0	NA
Plant height	3.2	8.6	15.0	0.0	8.3	15.3	8.8	5.0	NA
Shoot count	3.0	7.8	20.0	15.5	14.5	12.6	5.4	3.0	NA
Biomass yield	2.9	5.2	18.4	13.9	12.5	12.9	6.8	4.6	NA
Bara									
Acridity	0.0	0.0	0.0	0.0	19.0	19.0	20.0	20.0	20.0
Corm shape	1.7	0.0	0.0	1.6	15.3	17.3	14.4	0.0	13.7
Cormel size	2.0	0.3	0.8	1.2	15.4	16.6	10.3	0.0	14.4
Taste	0.0	0 0	0.0	0 0	17.2	10.0	22.6	19.0	17.0
Plant height	0.0	0 0	2.5	0 7	7.7	5.4	8.4	0.0	5.6
Shoot count	2.0	2 1	3.0	1.0	9.4	13.4	12.2	0.0	10.3
Biomass yield	1.0	0.0	0.0	2.9	6.1	9.0	17.6	5.1	10.9
p values (site)	0.00	0.00	0.01	0 00	0.55	0.63	0.01	0.68	
p values (trait)	0.93	0.37	0.37	0.29	0.65	0.86	0.77	0.48	
SE±	0.43	0.99	2.24	1.44	1.06	0.99	1.52	1.71	

NB: Weighted mean estimated response (n): 5 x n (good or positive effects) + 3 x n (medium) + 1 x n (poor or negative) divided by number of respondees. Greater score indicates positive associations (Chapter 6). 0 value stands for no response, NA- Not applicable.

Farmers responded that shoot counts, plant height and biomass yield may be better if the crop was grown in deep furrows rather than with flat planting. Unlike random planting methods, corm size decreases when grown in deep furrows, but the length may increase. The use of mulch may have positive impacts on biomass yield, shoot count, and plant height as well as on corms or cormel quality. There may be negative effects, however, on eating quality. The level of acridity increases for taros grown under excess soil moisture. Farmers stated that maintaining optimum soil moisture is essential to improve eating quality, corm size, plant heights and shoot numbers (Table 8.4). When corm size increases with improved soil moisture, a decrease in cormel size may result. Although taros are cultivated in a variety of soil types, heavier soils, more moisture and nutrients are preferred over lighter soils.

Kaski farmers stated that low external inputs have a variety of effects, particularly on plant height, tuber yield and shoot number. Overall, these were the main characteristics affected by the ecosystem factors also. The main effects of the latter on variety performance would be apparent if a cultivar was grown: a) from open fields grown under home gardens or agro-forest system; b) under changed fertility levels than from their traditional habitat; c) under varying soils types than in their traditional habitat and d) under different practices, including fertilisers that affect moisture, fertility and weed growth.

Bara farmers stated that planting methods, moisture status, soil types and sources of soil nutrients affect corms and cormel growth, acridity and eating quality. Taros produced with the deep furrows are considered superior to those grown under the flat method. It is believed that mulch can have negative impacts on corm shape and size, shoot number and yield, which are negatively affected by low moisture. The survey revealed that soil texture can have adverse effects on taro quality. Compared to sandy soils, taros produced in more clayey textured soils have better cormel size, taste, plant height and shoot numbers. Corm shape, cormel size, plant height and biomass yield was negatively affected where the level of external inputs was also low. Unlike the response of Kaski farmers, the Bara farmers reported no negative impacts of inorganic fertilisers.

Farmers consider traits are adaptive when their response to sunlight, soil fertility, and soil moisture become apparent. The response to sunlight is considered a key indicator of variety adaptation. Therefore, varieties adapted to home gardens are not preferred for open fields. The opposite may not always true, however. Previous studies have shown that different root crop species have varying levels of shade tolerance. In comparison to yam, cassava and sweet potatoes, aroids are more tolerant to shade. The chlorophyll concentration increased, while the chlorophyll *a:b* ratio, carotenoids per unit chlorophyll, and the weight per unit area of leaf were lower in the shade than in the sun. The change in levels was less in aroids than in other root crop species (Johnston and Onwueme, 1998). In their studies, no significant difference was found in shade tolerance between *Colocasia* and *Xanthosoma spp*. In this study, however, farmers clearly mentioned that cultivars of *Xanthosoma* spp have a higher degree of shade tolerance, i.e. high degree of localized adaptation.

Farmers' perceptions about local adaptation and adaptive traits in the study area were similar. They believe that growing cultivars outside of their traditional habitat can have manifold effects on their performance. When grown in open fields, the shade-loving taro cultivars may be affected in terms of cormel yield, plant height and petiole quality. Likewise, cultivars grown in home gardens are negatively affected when grown under mono-crop conditions. The performance of cultivars belonging to *Xanthosoma* spp was adversely affected when tested under open field conditions (Chapter 9).

Taro adaptations are described in terms of the relative performance of a set of economically important traits that are locally valued. This consideration is related to the complexity of the farming systems. To spread risks and exploit potentials represented by the imperfect markets in the hills of Nepal, farmers diversify the selection parameters. It was found that market-oriented farmers give greater priority to a few economic traits: yield and eating quality. On the other hand, small-scale farmers considered a large number of varieties to fulfill local needs and consumers' food preferences.

8.5.5 Dissemination of local ecological and botanical knowledge

Farmers exchange seeds along with information that describes individual varieties. The study revealed that farmers disseminate planting materials together with a maximum of 28 descriptors. They disseminate essential information during the exchange of planting materials (Table 8.5). Farmers pay attention to at least 12 different characteristics of each variety, most of which are common across study areas. A few characteristics are important for particular situations. Kaski farmers essentially seek information about local uses of plant parts, cropping systems and eating qualities. Bara farmers were keen on maturity duration, corm and cormel yield and for a suitable cropping system. Information on disease and pest resistance is transmitted along with planting materials as well as overall information related to the area of adaptation, local uses and cropping system type.

Table: 8.5 Top 10 post harvest information that is disseminated along with planting materials, Kaski and Bara (HH=35 each at Kaski & Bara) as recalled by farmers.

Type of information	No. farming households	
	Kaski	Bara
Uses of plant parts	20	2
Area of adaptation	19	21
Acridity	17	4
Cooking quality	12	29
Need for mulch	11	-
Yield	11	35
Planting method	10	6
Pest incidence	10	6
Planting time	10	-
Maturity days	6	23
Market price	-	3
Corm shape	-	2

Source: Household survey, 2003 (HH=35), - = not reported

8.5.6 Ecosystem factors and rice quality

Farmers believe that ecosystem factors affect quality traits such as aroma, taste, milling recovery, husk colour, husk thickness and eating quality, which in combination determine market price. Rice with a golden husk combined with a thin seed coat and no black spots fetches a premium price. Similarly, fine and aromatic varieties receive a better price than coarse non-aromatic varieties (Gauchan *et al*., 2005). Farmers claimed that ecosystem factors such as sources of irrigation water, soil water availability, soil texture, and fertility status affect product quality. They also said that product quality is better when the rice is grown with direct water sources, such as natural streams, as opposed to canal sources. Chemical fertilisers are claimed to have negative effects on product quality when rice is grown in soils with high inherent fertility. The farmers' experience was that rice grown organically is tastier than rice grown with chemical fertilisers. Locally, variety types are chosen according to soil texture. Product quality is better when varieties are grown on heavier soils (Table 8.6).

Table 8.6 Farmers' perceptions on the effects of environmental factors on post-harvest characters, Kaski (HH=105) and Bara (HH=70), Nepal.

Variety\characteristic	Ecosystem factors							
	Sources of water		Soil texture		Water availability		Soil fertility	
	Canal	Natural stream	Clayey	Sandy loam	Drought	Excess	Poor	Good
Coarse grain variety	2.9	3.6	3.3	2.8	2.2	3.6	2.9	3.7
Fine grain variety	2.4	3.3	3.8	2.6	2.4	3.3	2.3	4.0
Taste when cooked	2.4	3.1	3.4	2.8	2.9	4.0	2.2	3.8
Husk thickness	3.9	3.1	3 .6	2.9	2.7	3.3	2.4	3.7
Seed coat colour	2.8	3.1	3.5	2.8	2.3	3.8	2.5	3.2
Milling recovery	3.7	3.1	3.1	2.7	2.2	3.4	2.5	4.2
Aroma	3.2	3.9	3.6	2.7	2.3	3.6	2.9	3.8
Biomass yield	2.4	2.4	3.3	3.1	2.2	3.5	3.4	4.1
p values (sites)	0.02	0.01	0.04	0.00	0.02	0.00	0.00	0.00
p values (factors)	0.23	0.72	0.58	0.83	0.80	0.51	0.41	0.19

Source: Household survey (2003). Greater score indicate positive association / effects.

Earlier research documented similar perceptions among Nepali farmers. Quality rice is obtained when grown with natural spring water, organic fertilisers and no environmental stresses (Rijal *et al*., 1998). The performance of a certain trait may be obtained from a certain locality, which could be the reasons why some famous quality rice varieties of one geographic region are yet localised. A similar example comes from LI-BIRD work: the grain and eating quality of an aromatic fine rice from Pokhara, Nepal (Jethobudho) deteriorated when grown under similar environments in the Gulmi District. The researcher and farmers agreed that environment factors can affect such quality traits, though it is unexpected in the same environment over such a small geographic distance (LIBIRD, 1996/97). Tin *et al.* (2001) describe a local rice variety whose aromatic characteristic, according to the farmers, only emerges when grown in a particular village in the Mekong Delta. The aroma of basmati rice in India and Pakistan is known to depend on an interaction of genetic and environmental factors. Basmati rice is not aromatic when grown outside areas with an environment conducive to aroma development (Bhattacharjee *et al*., 2002). In the case of the study areas in Nepal, farmers' knowledge about how product quality may be affected by an interaction of variety and environment seems to have favoured the maintenance of varietal diversity.

8.5.7 Farmers' perceptions of rice variety adaptation

Adaptations may have different meaning for different people. The ecologists consider plant adaptation according to growth and reproduction under new environments while crop breeders describe adaptations with respect to agronomic performance. The farmers of both study areas, where people speak different languages, elaborate adaptation by 'performance of individual traits with economic importance'. Farmers compare adaptedness of new varieties to that of their own known variety/ies. Although farmers listed several parameters (n=26, H'=1.17-1.28), plant height, maturity duration, grain fertility, milling recovery and grain yield were key parameters of variety adaptation (Table 8.7). Crop varieties grown under certain environments can survive and reproduce under different ecosystems. Kaski and Bara farmers stated that introduced varieties are considered adapted only when they perform equal to or better than widely grown local varieties.

Table 8.7 Farmers preferred agronomic, ecological and post harvest characteristics across five rice ecosystems, Kaski (HH=105) and Bara (HH=70).

Descriptor	Household responses					Total (n=175)	
	Kaski			Bara		Freq.	Relative weight %[2]
	'Ghaiya'	'Tari'	'Sinchit'	'Ucha'	'Nicha'		
Tillering capacity	29	30	25	31	29	144	10.8
Inputs use efficient	40	39	46	4	8	137	10.2
Local adaptation	44	33	29	7	7	120	9.0
Milling recovery	41	40	37	0	0	118	8.8
Lodging characteristics	13	11	13	39	41	117	8.7
Maturity	23	11	15	28	23	100	7.5
Plant height	26	23	22	13	12	96	7.2
Taste when cooked	10	11	11	14	12	58	4.3
Market price	9	13	6	13	15	56	4.2
Panicle length	17	14	10	0	0	41	3.1
Tolerant to cold water	14	19	7	0	0	40	3.0
Comparative yield	4	6	8	9	12	39	2.9
Plant health	18	12	4	0	0	34	2.5
Pest tolerant	7	5	4	11	7	34	2.5
Grain filling	11	10	3	0	0	24	1.8
Tolerant to warm water	9	10	4	0	0	23	1.7
Tolerant to shade	7	7	9	0	0	23	1.7
Grain per panicle	6	5	8	0	0	19	1.4
Straw yield	6	6	4	0	0	16	1.2
Grain appearance	5	8	3	0	0	16	1.2
Flowering time	1	9	5	0	0	15	1.1
Tolerant to heat stress	5	7	3	0	0	15	1.1
Water use efficiency	6	5	0	0	0	11	0.8
Profuse root system	0	0	0	7	4	11	0.8
Aroma when cooked	5	3	3	0	0	11	0.8
Straw quality	2	0	9	0	0	11	0.8
Resistant to shattering	3	2	4	0	0	9	0.7
Total number of traits	26	25	25	11	11		100
H' value	1.265	1.280	1.166	1.144	1.107		

NB Farmers multiple responses may lead to exceed the total sample size for individual ecosystems.

Farmers observe and experience the effects of root growth while ploughing rice fields. They say that ploughing rice fields is easier in areas where rice varieties produce profuse root systems than areas where varieties have deep root system. Hence, root growth is also considered and included in adaptive traits. Also, traits related to input use efficiencies, responsiveness to varied soil types, tolerance of cold and hot water, and sometimes shade tolerance, are considered adaptive. The weight given to individual descriptors, however,

[2] Relative weight total responses for all descriptors divided by total responses for individual traits expressed in %.

differed across study areas. Ten descriptors were common across sites, 16 were specific for Kaski and one for Bara.

8.6 Discussion and conclusions

Farmers consider a large number of characters while assessing varietal adaptation. Adaptability of newly introduced varieties is compared with other locally adapted popular varieties. Although farmers listed numerous parameters, some are more important than others. In most instances, farmers evaluate varietal adaptability mainly with characters that have agronomic and economic values. The most common and important criteria include yield and yield components and quality traits. Farmers essentially share such key parameters while disseminating planting materials, which also reflect information about local adaptation. As revealed by the literature research (Chapters 3, 8 and 10) researchers define adaptations in different terms chiefly depending upon their background. The forage ecologists concerned with plant's survival and reproduction as essential processes of adaptation. The crop breeders describe variety adaptation based on the performance of some selected traits that have economic importance while the farmers define and measure variety adaptation on the basis of relative performance of individual traits important for local farmers or consumers. Unlike the forage ecologists or crop breeders who consider some selected parameters for describing adaptation farmers describe adaptation in a holistic manner. Like in formal research farmers assess variety adaptation against traits that have certain food (Acridity in taro and aroma in rice) and adaptive values (e.g. planting time, mixed cropping system).

The scientific literature mostly relates to dominant environments and diversity while local knowledge relates to agro-ecosystems and niches that favour the maintenance of a higher number of varieties as well as related knowledge. Farmers' knowledge includes the soils and their interaction with other ecosystem factors, particularly with respect to product quality. Farmers believe that rice is tastier when it is produced under heavier soils using irrigation and when organic fertilizers are applied. Chemical fertilizers are claimed to affect product quality, especially when applied in higher doses. Jarrell and Beverley (1986) described this as ‘growth dilution effects’. Since culturally valued trait(s) are affected by environmental factors and therefore landraces are being grown under specific growing environments and management practices. Despite low productivity, some landraces are still grown under favorable environments, especially those known for their superior qualities. The landraces that have greater adaptive characters are grown in stressed or marginal environments. Thus local environments, specific management practices and local adaptations have contributed to the maintenance of crop diversity on-farm. The preliminary research findings reveal that farmers hold rich knowledge about adaptation of their crops. In general, farmers cultivating several ecosystems and those who maintain richer diversity held rich ecological and botanical knowledge. Rice farmers cultivating more favourable environments not only held rich knowledge but also maintained rich diversity. This richness was because the farmers’ continue growing selected landraces together with varieties introduced from research stations. It is also evident that most introduced varieties are grown under favourable environments and most landraces under stressed or marginal environment. The results also show that some landraces are grown under favourable environment. The numbers of traits farmers used to describe adaptations was always higher for stressed environments compared to more favourable environments. Farmers’ consideration of a greater number of traits for marginal environments was not only to meet their needs but also avoid probable risks of crop failure due to unavoidable stresses. Since most landraces have greater potential to foil risks farmers often select them for marginal environments. Although crop scientists consider some key adaptive traits (Chapter 10) farmers select cultivars against a large number of traits especially for marginal environments. Whoever made the selections, a variety of traits are considered to ensure good harvest and to meet local needs. Distribution of this rich knowledge and diversity often go together, which is primarily maintained by wealthier households cultivating several environments. As found by this research, earlier researchers have also reported that these wealthier households make greater contribution to the maintenance of rice diversity in Nepal (e.g. Rana, 2004).

Farmers' knowledge is common across the agro-ecological zones. Although localized knowledge and diverse environments have enhanced diversity and culture, their potentials and limitations have yet to be fully understood by research. The field survey revealed that landraces might potentially adapt away from their traditional habitats and therefore further investigations are required to determine wide and narrow adaptation with reference to taro and rice. The following Chapters present research results of wide and narrow adaptation of taro and rice genotypes, experimentally tested under varying temperature, management and moisture gradients.

CHAPTER 9: ASSESSING WIDE AND NARROW ADAPTATION OF DIVERSITY OF TARO (*Colocasia esculenta*)

This Chapter presents the comparative performance of taro varieties tested under different altitudes and management practices. The varieties representing botanical groups were assessed together for their wide and narrow adaptation using a randomised complete block design with locally used practices. The main findings are presented along with their implications for on-farm conservation and future use.

9.1 Introduction

Taro (*Colocasia esculenta* (Araceae)) is the fourteenth most-consumed vegetable worldwide, especially in humid tropics and subtropics (Lebot and Aradhya, 1991). It originated in the Southeast Asian region although the exact origin, domestication and dispersal of taro are difficult to pinpoint (e.g. Lebot and Aradhya, 1991). The present day cultivated botanical varieties of *C esculenta* probably became domesticated in distinct geographic areas, leading to the development of *C esculenta* var. esculenta and var. anttiquorum (Ivancic and Lebot, 2000). Furthermore, Guman and Dongxiao (1990) found that diploid and triploid taros are distributed under different geographical conditions. Unlike diploid taros collected from the southernmost tropical Hainan province of China, most triploid taro varieties were widely distributed at higher elevations. The present-day taro also includes varieties of *Xanthosoma sagittifolium*.

Nepali farmers classify edible taros as *Pidalu (C esculenta* var. esculenta and *C esculenta* var. antiquorum) and *Karkalo (X sagittifolium)*, which are distributed under variable agro-ecosystems. Most varieties belonging to *C esculenta* var. anttiquorum are cultivated at high hill, while those of *C esculenta* var. esculenta in the *Tarai* plain (Chapter 6). At mid altitude site, both botanical varieties are grown under traditional systems. However, varieties of *X sagittifolium* are largely grown at mid altitude areas. Several studies have shown that traditional varieties of taro are strongly linked to environments and local use values (e.g. Matthews, 1995; Kahn, 1988). Jianchu *et al*., (2001) documented similar botanical varieties traditionally grown by Chinese farmers under different altitudinal gradients. Farmers distinguish diversity using five of the most common morphological characteristics- inflorescence, single corm, multi-corm, multiple cormel and petiole morphotypes.

Ivancic and Lebot (2000) classified taro diversity according to ecological adaptation: wetland, intermediate and upland. In Nepal, rich taro diversity was recorded in the mid hills. Unique heat tolerant (Ujarka), cold tolerant (Seto pindalu) and shade tolerant (Kalo karkalo) taro varieties have been reported (Chapter 6). Some varieties with diverse uses are grown more widely than those with specific uses. As elsewhere, Nepali farmers have been growing taro under upland as well as lowland conditions. For example, taros at mid hill and high hill are grown upland as opposed to in irrigated fields on the *Tarai* plain. As with other species, taro farmers select different planting practices according to their suitability to local conditions as well as to the scale of production. Taros produced on a small-scale are inter-cropped with other species, while those produced on a large scale are mono-cropped.

In mid and high hills, taros are planted using local compost and mulch. In contrast, *Tarai* farmers cultivate taros in lowland with the application of inorganic fertilisers and irrigation, but without mulch (Chapter 6).

The rate of nutrient uptake differs by the variety grown (Goenaga and Chardon, 1995). Along with variety specific characteristics, the availability of soil nutrients affects product quality. Hartemink *et al*. (2000) reported that increased nitrogen fertiliser doubled non-marketable corm and increased biomass yield. However, marketable corms were not affected. The plots that included mulch produced significantly heavier corm yield and a higher dry matter percentage. Miyasaka *et al.* (2001) reported that a significantly higher corm yield was produced in plots managed with mulch and weed control together with the use of organic or and/or inorganic fertilisers. In upland environments the use of mulch had greater positive effects compared to high inorganic fertilisers plus weed control. Mulching appeared to increase soil moisture content, which promoted both taro growth and conditions conducive to corm rot. Despite the wide distribution of taro diversity and knowledge, the issue of variety adaptability has not been extensively investigated.

Significant genotype and environment interaction due to origin or management practices may reflect genetic adaptation (Linhart and Grant, 1996). Ivancic and Lebot (2000) stated that taro is considered a less adaptive crop because it cannot respond quickly to new environmental changes due to its predominantly vegetative propagation. Despite the increasing accessibility of traditional varieties, little is known about adaptation and the adaptability of vegetative propagated species to different temperature and management factors. To date, the wide and narrow adaptation of Nepalese taro varieties-represented by botanical classes, geographic regions and probably ploidy levels in relation to temperature and location specific practices-has not been assessed by research before.

The comparative performance, one component of adaptability, of selected Nepalese taro varieties has been assessed in three representative areas of high hill, mid hill and the *Tarai* plain.

9.2 Materials and methods

9.2.1 Study areas

Two independent field experiments were conducted in 2001 and 2002. In 2001, the performance of selected varieties was assessed in the Jumla, Kaski and Bara districts that represent the high hills, mid hills and *Tarai* plain (Map 2.1). In 2002, some varieties were evaluated with three planting practices in the mid hills and on the *Tarai* plain. The general criteria used for selecting research sites included the representation of agro-ecological zones, crop ecosystems and variety diversity. Further details are presented in Chapter 2. A view of the experimental sites is presented in Plate 9.1.

9.2.2 Genotypes (2001)

A total of 21 taro varieties were recorded from the high hill (n=1), mid hills (n=19) and the *Tarai* plain (n=2) of Nepal. Table 9.1 presents a detailed description of selected varieties regarding local adaptation, botanical classes and agro-ecosystem. Following several rounds of discussions with farmers, the research team selected varieties that accurately represent:

- Agro-ecological zone (cold and heat tolerant)
- Distinct ecosystem (home garden, open field, mix crop)
- Botanical class (corm, cormel, leafy types)
- Typical use value (food dishes, acridity)
- Productivity level
- Typical adaptive value (soil fertility, moisture)

Out of a total of 7 varieties tested, 6 came from the mid hills and one from the high hills. The varieties tested during 2001 included ‘Khari’, ‘Khujure’, ‘Hattipow’, ‘Kalo karkalo’, ‘Panchamukhe’, ‘Dudhe karkalo’ and ‘Seto pidalu’ (Table 9.1). Inclusion of varieties from the *Tarai* plain was not possible in 2001.

Table: 9.1 Description of taro variety used for performance evaluation in high, mid and low altitude research sites, Nepal.

Variety	Botanical group	Origin	Year trialed	Adaptation and use
1. Khari	Single long corm	Mid hill	2001-2	Open fields as inter or sole crop
2. Khujure	Many cormel	Mid hill	2001	Open fields as inter crop
3. Hattipow	Round corm, sub-corm	Mid hill	2001-2	Uplands grown as inter or sole crop
4. Kalo karkalo	Leafy (*Xanthosoma*)	Mid hill	2001	Shade loving, moist soils, intercrop
5. Panchmukhe	Corm, cormel	Mid hill	2001	Open fields as intercropped
6. Dudhe karkalo	Cormel	Mid hill	2001	Shade loving,, agro-forestry
7. Seto pindalu	Cormel	High hill	2001-2	Cold tolerant, home garden Variety
8. Ujarka kanda	Single long corm	Plain *Tarai*	2002	Heat tolerant, in deep furrows

Varieties were grown according to the local practices of mid hill farmers. The crop was fertilised with farmyard manure. The experimental plots were mulched with locally available materials. The amount of organic fertiliser was applied as documented by previous surveys (Rana *et al.,* 2000). Further descriptions of the extent and distribution of diversity is given in Chapter 3.

9.2.3 Genotypes and planting practices (2002)

Through review and in consultation with farmers, different varieties and planting practices adopted by high hill, mid hill and *Tarai* farmers were identified. These practices hereafter are called high hill practice (PP1), mid hill practice (PP2) or *Tarai* practice (PP3). These were described in terms of planting methods, application of external inputs, and water management. The performance of selected varieties from the high hills ('Seto pidalu'), mid hills ('Khari', 'Hattipow') and *Tarai* plain ('Ujarka') was compared with different planting practices in the mid hills and on the *Tarai*. Table 9.1 details variety descriptions and Table 9.2 presents planting practices. The cropping period across the agro-ecological zones ranged from March to October. The seeds were planted as per farmers' practice. Field experiments were conducted between March and May.

Table 9.2 Planting practices (PP) adopted in the high hill (Jumla), mid hills (Kaski) and *Tarai* (Bara) sites, Nepal.

Practices	PP1 (High hills)	PP2 (Mid hills)	PP3 (*Tarai*)
1. Cropping patterns	Open field, upland	Open field, upland	Rice field, lowland
2. Cultivation practice	Random and flat	Random and flat	Deep furrows
3. Source of nutrient	Local compost	Local compost	Chemical fertilisers
4. Use of mulch	Rice, barley husk	Forest litters and twigs	No mulch
5. Irrigation	Rain fed	Rain fed	3-12 times

Source: Chapter 6; Baseline survey (1998)

9.2.4 Experimental design and data recording

In both years, the experimental treatments were arranged in a randomised complete block design with three replicates. A total of 25 plants were planted in a plot of 6.75 m^2. Prior to planting, seed tubers were disinfected with fungicides.

The data recorded include: 1) agronomic traits measured by researchers (IPGRI, 1999); 2) post-harvest morphological characters assessed by farmers; and 3) culinary traits evaluated by panellists. The evaluation of specific traits at various occasions is presented in Table 8.3 (Chapter 8). To get farmers' reactions, farmers identified from previous studies (e.g. Subedi *et al.*, 2002) were selected. The farmers who prepared a variety of dishes from taro, and for whom this crop is important, were chosen. These evaluated varieties with respect to post-harvest characteristics. The same group was involved in assessing variety performances.

9.2.5 Sensory evaluation

Culinary assessment of tested varieties was performed to observe the effects of different planting practices. A total of 10 male and 10 female panel members were invited. To obtain an unbiased response, panellists were served chocolate between each taste. The forms were supplied with a brief explanation and a score recorded by farmers. The overall weighted mean was calculated: the number of individual panel members x 5 for good, 3 for medium and 1 for poor, which was divided by the total number of panel members (Chapter 6):

$$\text{Preference ranking} = \sum_{i=1}^{n=N} \frac{5\,\text{x}\,\text{n} + 3\,\text{x}\,\text{n} + 1\,\text{x}\,\text{n}}{\text{N}}$$

9.2.6 Data analysis and interpretation

The data were analysed using two different statistical tools: a) partitioning of variance through the analysis of variance (ANOVA); and b) principal component analysis. Genotype and environment linear model enables a classical ANOVA to be conducted. We considered location, altitude and genotype as fixed factors. A reduced two-way ANOVA model was adopted for data analysis.

$y_{ijk} = m + G_i + E_j + (ge)_{ij} + e_{ijk}$ $i=1\ldots,n;\ j=1\ldots,\ n_e;\ k=1\ldots,\ n_r$

where m is the overall mean, G_i is the effect of genotype i, Ej is the effects of altitude j, $(ge)_{ij}$ is an interaction effect associated with genotype i and altitude j *and* e_{ijk} is the error associated with each measurement. Means were compared using Tukey's test: LSDα = (t α 0.05) * SE, where SE is the standard error of the mean difference and t is the tabular value at α level of significance with n error degrees of freedom. The methods and steps adopted for data analysis included:

1. Descriptive analyses performed to measure the variation of the experimental data as described by Steel and Torrie (1988) and used by Manzano *et al.* (2001) in taro studies.
2. Analysis of variance (ANOVA) performed for economically important measured variables using Minitab version 3.
3. Principal component analysis (PCA) was performed to determine the relationships between objects and measured variables. Prior to running the PCA, the data were standardised. Using the Unscrambler software package version 9.0 (camo@camo.no), the data were analysed to derive loadings and scores. Field data measured in each experiment and site were modelled.

9.3 Results

9.3.1 Performance of varieties across altitudinal gradients (2001)

Variety performance differed across altitudinal gradients. It was always better at mid hill than at high hill and the *Tarai* plain. Variety performance differed according to the botanical variety group. Compared to varieties that produce corms, performance was poor for varieties that produce cormels. Varieties that produce corms showed better performance on the *Tarai* plain, while those that produce cormel performed better under mid hill conditions. Unlike quality traits, most quantitative traits were affected by environmental factors. Compared to morphological traits, the yield and yield attributes were altered when varieties were tested outside their traditional habitats. The relationships between traits and varieties were analysed.

9.3.1.1 Plant count per plot

The plants that produced edible corm or cormel were considered to be plants that survived. The number of usable plants counted per plot differed across sites and varieties, as well as by site x variety interactions ($p<0.001$). Compared to the high hills and the *Tarai* plain, a higher number of plants was counted in the mid hills, but plant count differed among tested varieties, their origin and test sites. In general, a higher number of plants established for 'Khari', 'Khujure', 'Hattipow' and 'Kalo karkalo', while 'Seto pidalu' had the lowest plant count. 'Dudhe karkalo' always established itself poorly in the high hills and on the *Tarai* plain, while 'Panchamukhe' established itself poorly on the *Tarai* plain. In terms of plant count, tested varieties can be classed as: a) those that establish well across altitudinal gradients (Khari, Khujure, Hattipow, Kalo karkalo); and b) those that grow better in specific environments (Dudhe karkalo). This shows that plant establishment was dependent upon variety type: corms or cormels. Establishment was largely related to seed, soil and moisture conditions. The varieties with smaller size cormels were more affected than those with corm types. Further research is required to determine the specific factors responsible for plant survival.

9.3.1.2 Corm and cormel yield

The difference in total corm and cormel yield per plant was significant for site ($p<0.001$) and variety ($p<0.001$), as well as for site x variety interaction ($p<0.001$). The highest total yield was recorded for the mid hills, followed by the *Tarai* plain and high hills. The varieties that only produce cormels such as 'Kalo karkalo', 'Dudhe karkalo' and 'Seto pidalu', always produced lower yields (Table 8.3).

In the high hills, 'Khujure' produced the highest yield. Performance for the other varieties was poor. Despite a higher plant count, low yields were recorded for varieties that produce corms, and varieties producing cormels produced even lower yields. Despite good plant establishment, 'Kalo karkalo' produced a low yield (Table 9.3).

In the mid hill, although corm varieties ‘Khari’, ‘Hattipow’ produced significantly higher yields ($p<0.001$), this was not due to higher plant counts. ‘Kalo karkalo’ and ‘Dudhe karkalo’ with higher plant counts were amongst the low yielding varieties.

On the *Tarai* plain, no significant effects were detected although the varieties ‘Khari’, ‘Hattipow’ and ‘Panchamukhe’ gave higher yields, and the performance of varieties producing cormels was poor. This shows that varieties that produce cormels, especially ‘Dudhe karkalo’ and ‘Seto pidalu’, were different with respect to plant count, shoot count, plant height and yield (Table 9.3).

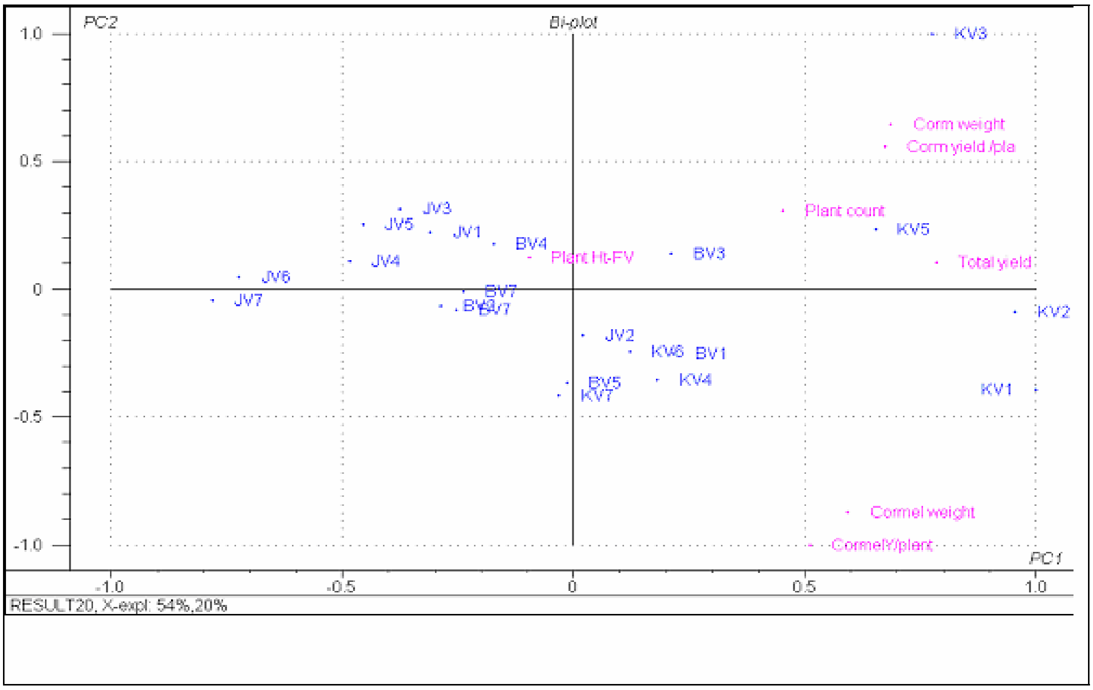
Table 9.3 Plant count (per plot), number of shoots per plant, plant height (cm) and total yield (kg per plant) recorded in field experiments conducted at Jumla, Kaski and Bara sites, Nepal (2001).

	Plant count				Shoot count				Plant height				Corm and cormel yield			
Variety name	Jumla	Kaski	Bara	Combined Analysis	Jumla	Kaski	Bara	Combined analysis	Jumla	Kaski	Bara	Combined analysis	Jumla	Kaski	Bara	Combined analysis
Khari	22	24	18	21	3.4	6.0	8.6	4.9	52	122	89	98	0.157	0.683	0.490	0.443
Khujure	24	23	19	22	2.3	2.7	3.2	2.8	59	110	55	91	0.270	0.713	0.190	0.3991
Hatipow	19	25	23	22	2.6	5.0	3.4	3.8	53	112	72	94	0.157	0.643	0.390	0.3696
Kalo karkalo	23	25	23	24	1.7	3.0	2.6	2.4	40	71	60	63	0.060	0.313	0.213	0.1956
Panchamukhe	23	24	16	21	2.5	8.3	6.5	5.5	51	106	65	88	0.080	0.567	0.383	0.3433
Dudhe karkalo	10	25	11	15	1.5	2.7	2.6	2.1	29	56	64	47	0.033	0.293	0.353	0.2267
Seto pindalu	4	12	11	9	1.2	4.0	3.8	2.8	29	56	58	42	0.063	0.450	0.340	0.2844
Mean	18	22	17	-	2.2	4.5	4.4		45	89	90	-	0.117	0.523	0.337	-
p (Variety)	0.000	0.000	0.004	0.000	0.059	0.000	0.00	0.000	0.00	0.00	0.259	0.000	0.000	0.004	0.134	0.000
p (Site)	-	-	-	0.000	-	-	-	0.000	-	-	-	0.000	-	-	-	0.000
p (Interaction)	-	-	-	0.000	-	-	-	0.221	-	-	-	0.001	-	-	-	0.003

Performance of some varieties was different than others. Yield data were statistically analysed excluding ‘Khujure’ and/or ‘Kalo karkalo’. The statistical significance was removed when analysed with or without ‘Khujure’. The exclusion of ‘Kalo karkalo’ did not significantly change the statistical differences ($p<0.013$ to $p<0.018$).

When run with seven yield and yield attributes, planting practices, PC1 and PC2 accounted for a 74% systematic variation (Figure 9.1). In terms of performance, varieties clustered together according to their test sites. The *Tarai* plain tended to cluster around the PC coordinate origin and represent an average environment. The performance of varieties was strongly correlated with corm yield, plant count and total yield. The cormel type ‘Seto pidalu’ was distinctly inferior.

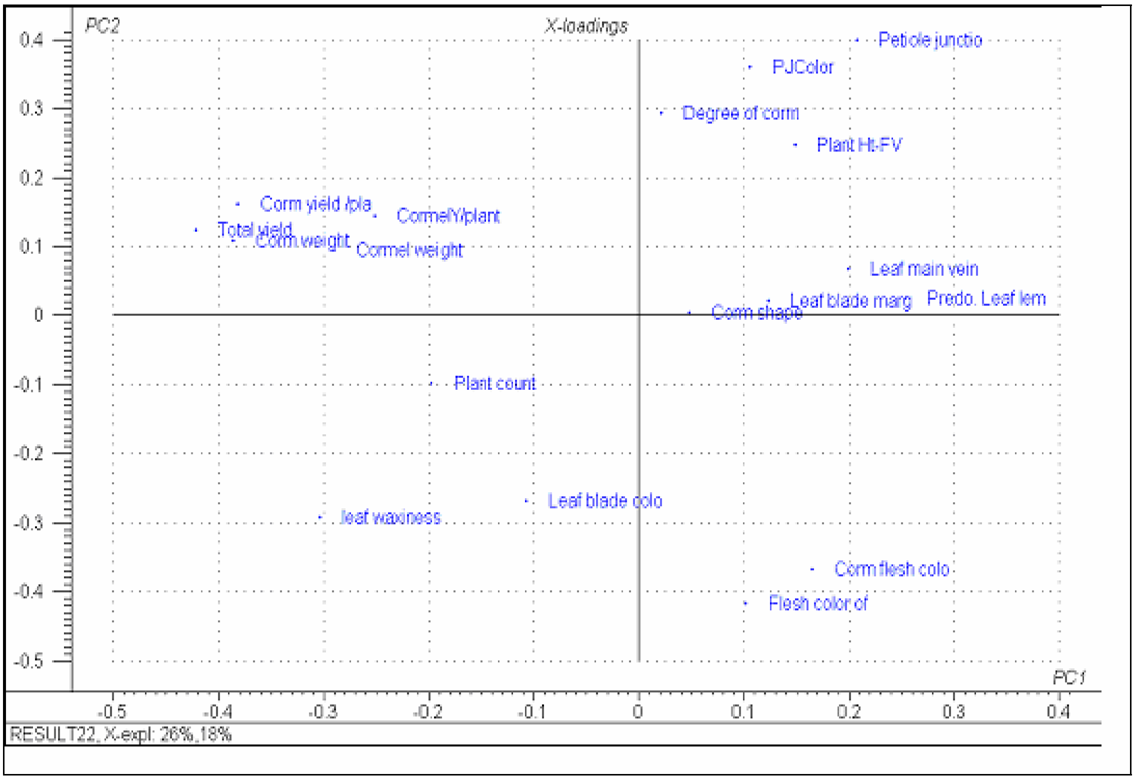
Figure 9.1 Biplot revealed by PCA for taro varieties with seven yield and yield attributes measured in Jumla, Kaski and Bara sites, Nepal (2001).



Letters denote sites: J=Jumla, K=Kaski, B=Bara and V for variety and names: 1=‘Khari’ 2=,Khujure, 3= Hattipow, 4= Kalo karkalo, 5= Panchamukhe 6= Dudhe karkalo, 7= Seto pidalu.

The traits can be grouped into two distinct clusters (Figure 9.2). The first cluster was related to yield and yield attributes. There was a strong and positive correlation between tuber yield and yield attributes. In addition to corm and cormel yields, taro varieties were evaluated for their yield and quality of petiole and leaf. Plant growth and a petiole junction pattern contributed most to variation. PCA revealed that the colour of the petiole junction pattern and corm or cormel flesh colour were weakly related. Corm and cormel flesh colours were not directly correlated with leaf blade colour (Figure 9.2). Although taro pigmentation does not affect the marketability of the produce, these traits distinguish diversity.

Figure 9.2 Loadings plot for agronomic traits measured at the Jumla, Kaski and Bara sites, Nepal.



The varieties that have high quality petioles and leaves (see Chapter 5) often produced a low tuber yield. This trend was opposite for varieties that produce corms. In terms of response to environment, the varieties tested could be grouped into three categories: 1) varieties that are known for quality petiole and leaves, but produce low cormel yield, 2) varieties known for quality corms, cormels, petioles and leaf, and 3) varieties that produce high corm yield. ANOVA results provide further supportive evidence (Table 9.3).

9.3.2 Performance of varieties across altitude and planting practices (2002)

9.3.2.1 Corm and cormel yield

The combined analysis revealed significant differences among varieties ($p<0.001$) and planting practices ($p<0.001$). Regardless of planting practices, yield difference among varieties was significant ($p<0.001$). The variety ‘Khari’ produced the highest tuber yield, followed by ‘Ujarka’; the lowest was ‘Seto pidalu’. Performance was planting practice specific. Across all sites, taro productivity was always high with the *Tarai* practice as opposed to random planting, regardless of what varieties were planted. Further details are presented in Table 9.4.

The interaction between site and variety was barely significant ($p<0.044$). At mid hill, ‘Khari’ produced the highest tuber yield, followed by ‘Hattipow’ and ‘Ujarka’. On the *Tarai* plain, ‘Khari’ and ‘Ujarka’ produced higher yields. In contrast, ‘Seto pidalu’ always produced the lowest yield. The interactions between planting practice and variety, as well as between sites, varieties and planting practices were insignificant.

The varieties that produce corms (Ujarka, Khari and Hattipow) showed a positive association with high inputs as applied according to the *Tarai* practice. There were significant site-variety interactions. The performance of the varieties from the *Tarai* plain and high hills decreased when grown in the mid hills, while the variety ‘Ujarka’ outperformed other varieties on the *Tarai* plain, over when grown with mid hill practices. ‘Seto pindalu’ was hindered when grown with mid hill or *Tarai* practices. There was no interaction between variety and planting practices with respect to corm or cormel yields.

Table 9.4 Combined analysis of number of corm and cormel (per plant) and their weight (kg) measured in taro field experiments conducted at the Kaski and Bara sites, Nepal, 2002.

Treatment	No. of corms		Combined	Corm weight		Combined	No. of cormel		Combined	Cormel weight		Combined
	Kaski	Bara	analysis	Kaski	Bara	analysis	Kaski	Bara	analysis	Kaski	Bara	Analysis
Planting practices (PP)												
High hill practice	17.5	21.25	19.25	4.53	4.99	4.76	61.5	88.5	75	1.67	2.40	2.025
Mid hill practice	19.25	19.25	19.5	7.47	4.93	6.2	84.33	74.5	79.5	2.61	2.40	2.5
Tarai pratice	17	18.25	17.5	6.65	8.475	7.57	50.93	50.25	50.25	1.51	2.70	2.1
Cultivars (CV)												
Ujarka	15.7	18.7	18.0	6.3	7.7	7.0	34.0	53.3	43.3	1.6	3.00	2.3
Seto pidalu	15.7	17.3	16.7	2.4	2.4	2.4	118.5	106.3	112.3	2.2	1.10	1.7
Hatipow	19.0	19.7	19.3	9.1	7.8	8.5	10.2	23.3	17.0	0.3	1.10	0.7
Khari	19.7	22.7	21.0	7.0	6.6	6.8	99.7	101.3	100.3	3.6	4.60	4.1
Mean values	**17.9**	**19.6**	**18.8**	**6.2**	**6.1**	**6.17**	**65.6**	**71.1**	**68.25**	**1.9**	**2.50**	**2.19**
p (Site)			0.001			0.834			0.32			0.020
p=Practices	0.058	0.179	0.117	0.000	0.000	0.000	0.012	0.000	0.000	0.003	0.885	0.143
p=Cultivar	0.007	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
p=Site x CV			0.756			0.149			0.167			0.001
p= Site x PP			0.129			0.000			0.021			0.045
p = PP x CV	0.093	0.714	0.543	0.238	0.207	0.174	0.043	0.261	0.068	0.026	0.81	0.382

9.3.2.2 Shape and size of corm and cormel

ANOVA was performed considering all two sites as replicates. This gave significant effects due to planting practices on corm ($p<0.001$) and cormel length ($p<0.01$). The effects of planting practice on corm or cormel width were insignificant, although *Tarai* practice produced the longest corm (17 cm) and cormel (11cm). The patterns depended upon the origin of varieties. The corm length of 'Hattipow' (mid hills) increased when grown with the *Tarai* practice compared to high hill and mid hill practices. Corm of 'Ujarka' (*Tarai*) was always longer when grown with *Tarai* practice, but corm width increased when grown in the mid hills (Table 9.5 and Plate 9.1). Cormel width was also higher when planted randomly as per mid hill practice. The changes in length and width of corms and cormel were related to planting practice. Compared to flat methods, roots planted in deep furrows always produced longer corms and cormels. However, their length and width were inversely correlated with each other. The changes on corm shape and size affect market demand, as some consumers prefer longer corms, such as on the *Tarai* plain.

Table 9.5 Effects of planting practice on corm and cormel sizes (cm) on taro varieties, Kaski and Bara, Nepal, 2002.

Treatments	Corm length	Corm width	Cormel length	Cormel width
Cultivars (CV)				
Khari	15.93	6.30	10.73	3.23
Hattilow	9.87	9.83	6.37	4.00
Ujarka	13.97	7.23	8.27	3.37
Seto pidalu	9.63	6.23	7.80	2.23
Planting practices (PP)				
High hill practice	8.95	7.35	6.43	3.38
Mid hill practice	10.25	8.08	6.83	3.15
Tarai practice	17.85	6.78	11.63	3.1
Mean values	**12.35**	**7.40**	**8.29**	**3.21**
p value (CV)	0.00	0.04	0.17	0.00
p value (PP)	0.000	0.49	0.01	0.48
p value (PP*CV)	0.64	0.84	0.19	0.90

9.3.2.3 Corm, cormel yield and yield attributes

Combined analysis at all three sites revealed significant varietal differences for the number of corms per plant ($p<0.001$), cormel weight ($p<0.02$), number of shoots per plant ($p<0.001$), plant height ($p<0.001$), leaf length and leaf width ($p<0.001$). Differences in other traits were insignificant. Different planting practices had a significant influence, especially on the number of shoots per plant, mean plant height, leaf length and number of cormels per plant ($p<0.001$); more shoots per plant, taller plant height, longer leaf length and a higher number of cormels were recorded. Observations not affected by planting practice included plant counts, number of corms, and cormel weight. The differences between varieties for a number of traits were significant ($p<0.001$) (Table 9.6).

In the mid hills, the difference due to the types of variety was significant for a number of traits: plant count, shoot count, plant height, leaf length and width, number of corms and cormels, as well as corm and cormel weight ($p<0.001$). With respect to plant count and plant height, the variety 'Khari' was superior.

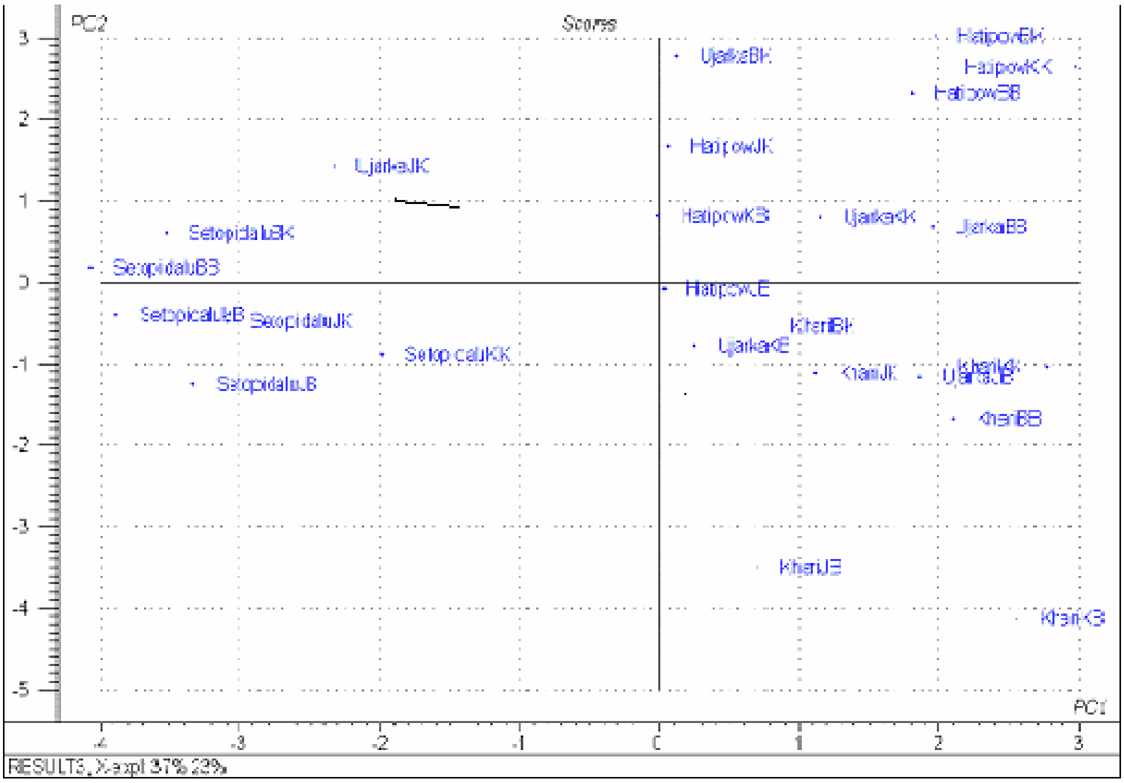
The effects of planting practice were significant for all traits analysed above (Table 9.6). The higher plant establishment was recorded when planted with the *Tarai* practice, while the shortest plants and the lowest number of shoots were also recorded. The random method of planting not only yielded a larger number of corms and cormels, but also produced higher yield. In contrast, the *Tarai* practice produced the lowest numbers of cormels and total cormel yield. The interactions between planting practices and varieties were barely significant for leaf length, number of cormel and comel weight ($p<0.05$).

Table 9.6 Combined analysis of plant count (per plot), shoot count (per plant), mean leaf length and width (cm) measured in taro field experiments conducted at the Kaski and Bara sites, Nepal, 2002.

Treatment	Plant count		Combined analysis	Shoot count		Combined Analysis	Mean height		Combined analysis	Leaf length		Combined analysis	Leaf width		Combined analysis
	Kaski	Bara		Kaski	Bara		Kaski	Bara		Kaski	Bara		Kaski	Bara	
Planting practices (PP)															
High hill practice	20.25	21.5	20.7	3.8	5.7	4.7	73.5	57.6	65.7	32.575	27.5	30.5	22.5	19.6	21
Mid hill practice	22.5	23.3	23	4.3	5.3	4.8	96.75	58.8	77.5	39.825	27.7	33.7	27.6	20	24
Tarai practice	23	21.5	22.3	3.3	3.8	3.55	68.7	51.1	60.25	32.925	24.3	28.7	21.8	17.2	19.75
Cultivars (CV)															
Ujarka	17.3	23.3	20.3	4.0	5.7	4.9	74.7	65.8	70.3	34.1	30.5	32.3	21.9	20.8	21,7
Seto pidalu	22.7	19.3	20.7	3.1	2.5	2.8	58.6	32.9	46.0	25.7	16.1	21.3	18.7	12.5	15,7
Hattipow	23.3	23.7	23.7	3.3	4.2	3.8	88.0	57.5	72.7	46.5	31.3	39.0	32.7	23.0	27,7
Khari	24.3	22.0	23.3	4.8	7.2	6.0	97.3	67.3	82.3	34.1	28.1	31.3	22.5	19.4	21,3
Overall mean	**21.9**	**22.1**	**22**	**3.8**	**4.9**	**4.35**	**79.7**	**55.9**	**67.8**	**35.1**	**26.5**	**31**	**24.0**	**18.9**	**21.6**
p (Site)			0.822			0.000			0.000			0.000			0.000
p=PP	0.002	0.104	0.005	0.006	0.004	0.000	0.000	0.020	0.000	0.002	0.087	0.001	0.000	0.04	0.000
p=Variety	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
p=Site x CV			0.000			0.000			0.007			0.001			0.001
p= Site x PP			0.055			0.086			0.001			0.032			0.03
p=PP x CV	0.073	0.573	0.037	0.669	0.256	0.434	0.159	0.618	0.421	0.020	0.108	0.029	0.321	0.071	0.024

On the *Tarai* plain, variety differences were significant for all measured traits (Table 9.6). The effect of planting practices was significant, particularly on shoot count, plant height, leaf width, corm weight and number of cormels ($p<0.05$). Interactions between variety x planting practice were insignificant for all measured traits ($p<0.05$). The PC1 (37%) mainly displays the yield differences between 'Seto pidalu' and the others. PC2 displays cormel weight versus cormel length (Figure 9.3a).

Figure: 9.3a Scores plot for taro variety by cultivation practices, Kaski and Bara, Nepal, 2002.

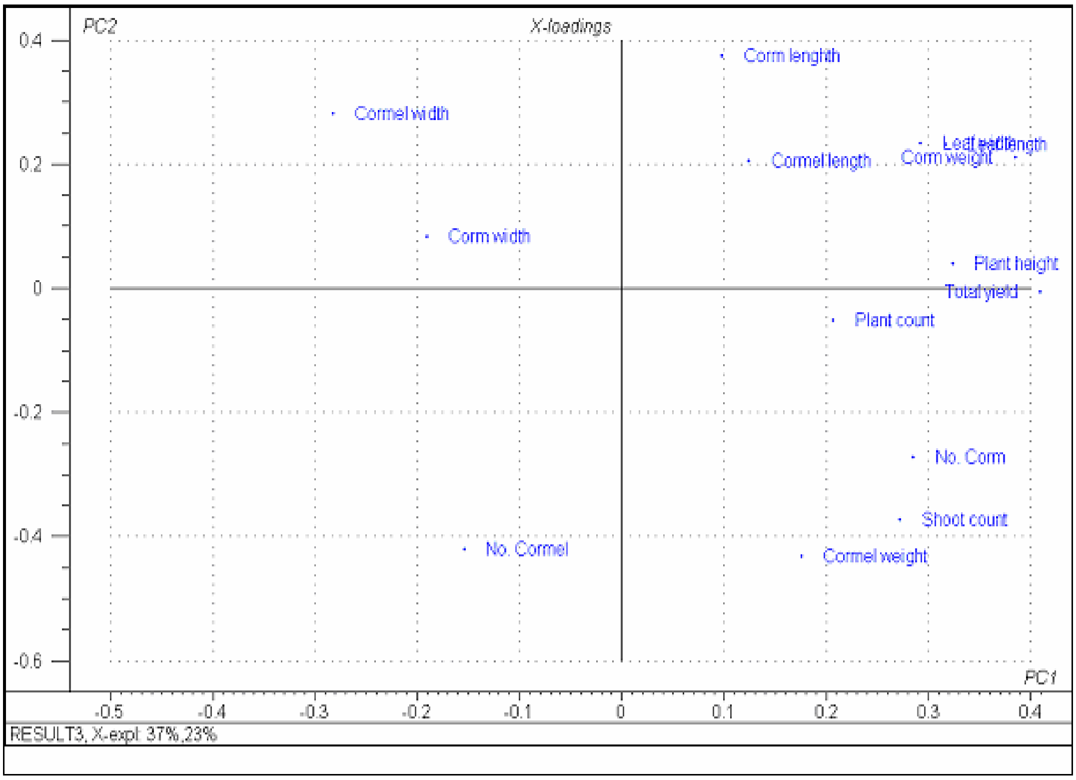


Last two letters represent practices (J=Jumla, K=Kaski, B=Bara) and sites (K=Kaski, B=Bara), respectively

The length of corm and cormel, corm weight, and leaf length and width spread showed strong correlations upper right. Corm length and corm weight showed strong and positive correlations. A similar correlation was evident for leaf length and leaf width. Plant height, plant count and total yield showed positive correlations. The number of corms and corm weight was also inversely correlated. The number and weight of cormels were inversely related. A large number of cormels does not necessarily produce higher cormel yield (Figure

9.3b). The length and width of corm and cormel was greater when ‘Hattipow’ with round shaped corms was planted according to the *Tarai* practice. Most yield and yield attributes were weakly correlated with the variety ‘Seto pidalu’, regardless of planting practice.

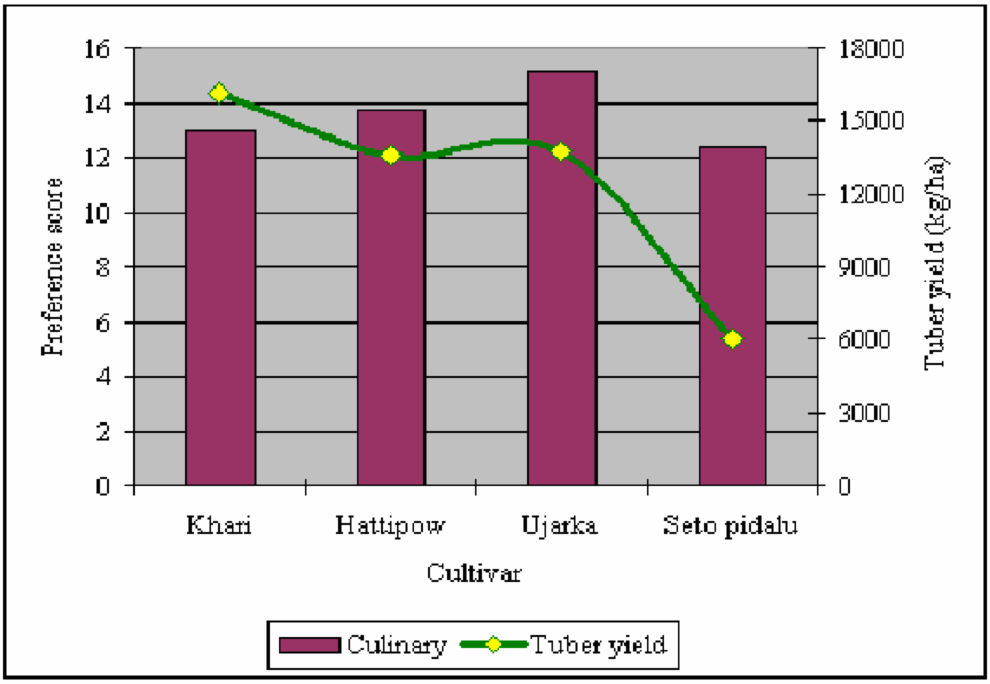
Figure: 9.3b Loadings plot for taro variety and planting practice from Kaski and Bara sites, Nepal.



9.3.2.4 Farmers’ assessment of varieties and planting practices

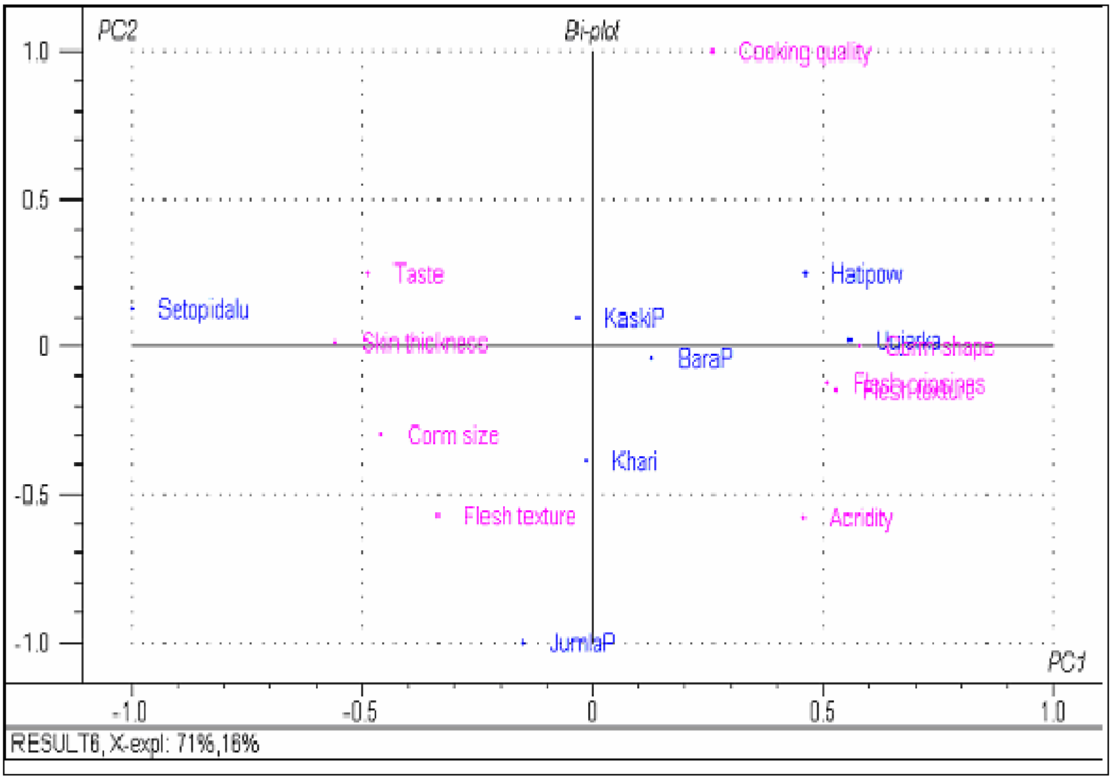
A PCA of average farmers’ preferences revealed that 61% of the variance was due to variety. ‘Seto pidalu’ was one group having superior taste, but low acridity, inferior cooking quality and a low ranking in terms of morphological traits. ‘Khari’ was intermediate, whereas ‘Hattipow’ and ‘Ujarka’ were corm varieties that got high scores for their traits, especially among female panellists. The effects of planting practice were limited, except that high hill practice tended to reduce cooking quality. A more detailed analysis showed that planting practices affected product quality, and farmers agreed that inorganic fertilisers had a negative impact on quality (Figure 9.4, Figure 9.5).

Figure 9.4 Farmers' assessment of taro varieties for different culinary traits in Kaski and Bara, Nepal



As elaborated in the previous Chapter farmers' perception regarding effects of inorganic fertilisers on product qualities differs between farmers at mid hills and on the *Tarai.* Sensory evaluation of cooked corms or cormels revealed that panellists did not experience such apparent distinctions between varieties grown with organic and inorganic fertilisers. Farmers' preference was determined according to the performance of individual attributes.

Figure: 9.5 Bi-plot for farmers' preferences of planting practices, variety with regard to post harvest traits, Kaski and Bara, Nepal.



Last capital letter denotes planting practice (K=Kaski, B=Tarai practice, J=Jumla)

9.4 Discussion and conclusions

9.4.1 Taro adaptation across altitudinal gradients

Variety adaptation differed by botanical group. Environment (soil/water) effects were apparent on a variety of agronomic traits including plant establishment, number of shoots produced per plant, plant height and total yield. Similarly, effects of climatic factors were evident on plant count, plant height, corms and cormel yields. The lowest plant counts were recorded in 'Seto pidalu' and 'Dudhe karkalo'. In contrast, 'Hattipow' and 'Kalo karkalo' had the highest plant establishment (>80%), for other varieties it ranged from 60 to 80%. Regardless of variety, average performance was always better on the mid hill site.

Performance of the high hill variety improved when grown at mid hill. The varieties from mid hill outperformed it when grown at high hill, showing wide adaptation. Traditionally, varieties are exchanged among farmers through several informal networks, including migration, seasonal migration, and visits with relatives and friends. The people engaged in business and off-farm jobs disseminate planting information while travelling from place to place. Jumla farmers introduced taro from Jajarkot district of the same region. Kaski farmers recalled several taro varieties introduced by their relatives and friends while travelling outside villages and abroad. In the same manner, several varieties have been taken out of the locality by their relatives and friends. It is important to note that farmers manage different botanical varieties in the high hill and on the *Tarai* plain. The *Tarai* farmers prefer varieties that produce corms, while at high hill varieties are grown that produce cormel. In the mid hills, however, farmers have been maintaining both types of varieties that produce corms and cormels. The reasons for this distribution of botanical group across different geographic regions are unclear.

Our research shows that varieties produce corms tended to perform better in the mid hills and on the *Tarai* plain than in the high hills. Varieties that produce cormels yielded better when cultivated at the high altitude site. ‘Khujure’ that produce cormels performed better in the mid and high hills, but performed poorly under *Tarai* condition. The varieties ‘Hattipow’ and ‘Khari’ which pre-dominantly produce corms yielded high in mid hill and their performance decreased when grown away from homeland. Their performance under high hills and *Tarai* conditions was comparable to other native varieties. In general, these performed better in warmer condition than at higher elevations. Previous studies have shown that adaptability of taro differs according to botanical variety (Ivancic and Lebot, 2000; Guman and Dongxiao, 1990). Our research findings largely agree with this. My research results can have different implications for farmers’ management of taro diversity and rural livelihoods.

Unlike traditional practice, where agro-ecological zone specific varieties are grown, field validation revealed that taro varieties grow widely across climatic conditions. Through direct introduction of widely adapted taro varieties into the high hills, where farmers' choice for potential varieties has been minimal, enhances diversity and livelihoods. Since farmers have adapted location specific knowledge and cultivation practices their introduction away from their traditional habitats requires field validation. Chapter 5 documents that taro uses and cultivation practices varied by agro-ecological zone. The following section states the implications of empirical research findings of different location-specific management practices on taro diversity, originated from three contrasting agro-ecological zones.

9.4.2 Impact of planting practice

In taro, corm and cormel yields and the quality of leaf, petiole and culinary traits are locally preferred traits. The assessment of varietal performance has therefore been performed on the basis of these traits. The performance of these traits is affected by several environmental and farmer-managed factors. Table 9.3 elaborates different planting practices that affect productivity potential and product quality. Results show that the *Tarai* practice produced higher yields, followed by the mid hill and high hill practice, respectively. Varietal performances were affected by several factors including soil nutrients, soil moisture availability and planting methods. *Tarai* farmers cultivate taros with the application of chemical fertilisers, irrigation and weed control, the key factors that determine productivity. Hence, the poorer performance of high and mid hill practices is due to reduced management for soil fertility, weeds and soil moisture. Hartemink *et al*., (2000) also reported that an increased application of nitrogen fertiliser had no effect on the marketable corm yield, but non-marketable corm yield doubled along with an increase in biomass production. Farmers' assessment was that taros produced under different practices affected tuber yield. *Tarai* practice always out-yielded mid hill and high hill practices. However, *Tarai* practice affected the shape and size of corms and cormel especially varieties with round corms introduced from the mid or high hills. Rogers and Iosepha (1993) reported that the best quality corm could be obtained from a shaded field without mulch. The localised practices are associated with land use systems combined with local preferences. Such location-specific practices could be adapted under conditions in which consumers' preferences are common across locations (Chapter 5). This research also revealed that taros grown without shade and mulch still produce high quality corms and cormels. As discussed in Chapter 5, *Tarai* farmers have never experienced the negative effects of their improved management practices on product quality. By contrast, Kaski farmers expressed that the application of chemical fertilisers and no mulching negatively affects taro product qualities. Organoleptic assessment revealed that planting practice had no significant effect on eating qualities. The shapes of corms were affected by deep furrow methods. Further studies are required to assert the extent of marketability of such corms produced under varying planting practices.

The difference between varieties was significant with respect to shoot count, mean plant height, leaf length and breadth, numbers of corms, cormels, corm and cormel yield. 'Ujarka' outperformed the others when grown with *Tarai* practice. This variety which produces the long corm performed better in the mid hills when grown with the mid hill practice than when grown with high hill practice. 'Ujarka' performed better in its homeland (*Tarai*) grown with the mid hill practice. Thus the assessment of adaptability of crop diversity enriches knowledge for sustainable management of taro diversity on-farm in different ways:

i) Promotion of widely adapted varieties to diversity-poor areas where farmers' choices for varieties are limited, enhances diversity conservation through increased uses,

ii) Introduction of varieties with special uses may enhance diversity and knowledge, provided farmers receive planting materials along with information related to their special use values

iii) The scientists provide alternative options based on the performance of individual varieties tested under selected environment and management conditions. Such research provides farmers' basis to further structure or restructure crop diversity on-farm that enhance livelihoods.

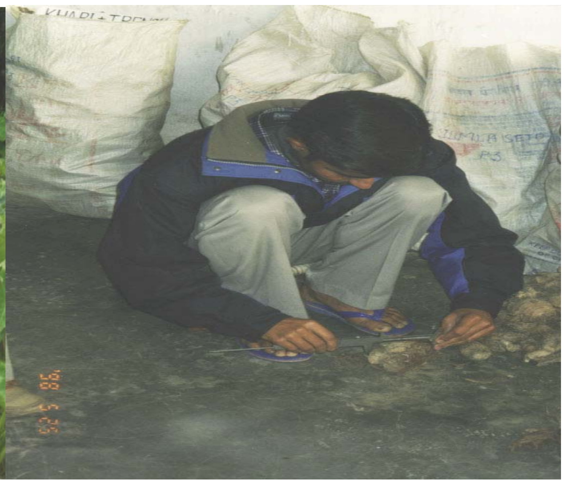
Map 9.1: Overview of experimental activities.

High hills (Jumla)

Planting practice and variety type

Mid hills (Kaski)

Farmers' assessment of corms and cormels



Tarai plain (Bara)

Researchers' measurement of corms and cormel

CHAPTER 10: ASSESSING WIDE AND NARROW ADAPTATION OF RICE LANDRACES (*Oryza sativa* L)

In this chapter, results are presented of wide and narrow adaptation of local rice varieties, experimentally assessed at different rice ecosystems independently at high hill, mid hill and *Tarai* plain sites. Improved varieties recommended for individual ecosystems were tested together with landraces. The implications of the research findings to on-farm conservation are discussed and the need for further considerations is indicated.

10.1 Introduction

Adaptations in plants can be described in different ways. According to Allard (1988), adaptedness is the degree to which an organism is able to live and reproduce in a given set of environments. Ceccarelli (1989) argued that in crop plants, adaptation approximates to yield stability over time and environments. Superior adaptations in crop species are equated with heavier yields and their stability (Cooper and Byth, 1996). Breeders often have difficulties with efficient selection of improved varieties because of high genotype (G) x environment (E) interactions (Wade *et al.*,1999). The conventional method is wide spread testing across multiple locations. The outcome may be the recommendation of a “widely adapted” variety with little G x E.

During the 1960s and 1970s, rice research efforts were focused on developing high yielding varieties with wide adaptation (Fisher, 1996; Dalrymple, 1985; Anderson *et al.,*1985). As a consequence, many farmers adopted these improved varieties mainly for their high grain yields. A recurrent debate has been how “wide” is wide. The answer depends upon the species, the environments and the genotypes sampled. For example, a study conducted with varying input levels shows that improved rice varieties consistently produce higher yields, especially under high input conditions (Romyen *et al.,*1998). In contrast, a high degree of G x E interaction was observed under low input conditions (Wonprasaid *et al.,*1996). The research methods through which varieties are developed are important because the performance is related to genotypes and the environments in which varieties were tested.

Vega (1997) stated that plant adaptedness is evaluated in different ways, depending chiefly upon the researcher's background. Ecologists assess G x E interaction in reciprocal replant-transplant experiments in environments with contrasting selection pressures, such as different climates or soil conditions (Bradshaw, 1984; Linhart and Grant, 1996; Joshi *et al*., 2001). The ecologists prefer 'common garden' experiments while crop breeders assess G x E interactions in multi-location trials under similar soil types and moisture regimes (Rajaram, 1997; Ceccarelli, 1989). Such multi-location trial approach does not fully represent the environmental variation that exists within the same geographic region. The earlier studies have shown that Nepali farmers cultivate different rice varieties under, i) specific moisture regimes or niches; ii) similar moisture regimes to traditional growing environment; and iii) wide moisture regimes (Rijal *et al*., 1998). Traditional farmers select the growing environment for introduced varieties according to the information that comes along with the seeds. Crop varieties introduced from unknown sources are often grown under representative rice growing environments. However, farmers rarely grow crop varieties under different rice environments to determine their adaptability. Nepali farmers claim that they have identified local rice varieties suitable for specific ecosystems (Soleri *et al*., 2002; Rijal *et al*., 1998).

Crop breeders often examine a variety of adaptations with reference to a few selected traits, primarily grain yield (e.g. Ceccarelli, 1989), though grain yield encompasses several attributes. Adaptation in wheat is assessed based on yield together with other yield attributes e.g. drought tolerance (Rajaram *et al*., 1997). The forage ecologists assess adaptation based on selected traits such as species survival, seed formation, or phenological characteristics (Joshi *et al*., 2001). Unlike conventional research where cultivar adaptation is evaluated against yield and some selected yield attributes, farmers may consider other selection criteria according to their own diverse needs and preferences. Since adaptive traits were unknown, in consultation with rice breeders and farmers the researcher measured wide and narrow adaptation against a large number of morphological, agronomic, phenological and post-harvest characteristics, including culinary traits.

In order to compare the adaptedness, the performance of Nepalese rice varieties was assessed under different moisture regimes within a narrow geographic range. Field experiments were conducted to study i) wide and narrow adaptation of local varieties traditionally grown in specific ecosystem; b) wide and narrow adaptation of improved varieties recommended for specific ecosystem; c) expression of individual traits when grown under different ecosystems; and d) the potential of traditional varieties to grow away from their traditional habitats. Potential implications of the research findings are analysed, especially whether farmers' benefits and on-farm conservation can go hand in hand.

10.2 Materials and methods

10.2.1 Rice ecosystems

Farmers distinguish rice environments by different names. The vernacular names, literal meanings, and salient features of the rice environments in which this research was conducted are described in Table 10.1. In the high hills, rice environments are named according to the source of irrigation water: from stream sources (Gadkule) or glacial melt waters (Kholapane).

Whereas mid hill farmers distinguish rice environments by the ways water are managed as well as by how the crop is cultivated - transplanted or directly sown. Local practices differ according to the ecosystem - cultivation method, sowing or transplanting time and weeding intensity. On the *Tarai* plain, rice ecosystems are called *Ucha* (Rain fed) and *Nicha* (Lowland). These ecosystems are distinguished by access to irrigation water, soil fertility, soil texture and soil colour. The amount of chemical fertilisers used varies by location and ecosystem. In the high hills, chemical fertilisers are not used, but the amount used for landraces on the *Tarai* plain and mid hills was similar (Rana *et al*., 1999). The major soils nutrients were compared irrespective of rice ecosystems. An overview of rice ecosystems across all sites is presented in map 10.1.

Comparison of soil analysis from mid hills and on the *Tarai* plain sites showed no differences for nitrogen, organic matter, phosphorus, or clay content ($p<0.01$). The difference for soil pH and potassium was significant ($p<0.01$). Soil pH across all ecosystems ranged from 5.0 to 7.5 but pH was always low in the mid hills. Nitrogen varied over individual ecosystems. Unlike the *Tarai* plain and mid hill, soils at high hill were rich in nitrogen and organic matter. Compared to uplands, soils of the *Tarai* plain were more fertile. This does not mean that high hill soils are always fertile. In terms of texture, soils were classified as sandy loam, loam, sandy clay loam or clay loam.

10.2.2 Genotypes

Nepali farmers have been growing different rice varieties over the agro-ecological zones. Most landraces are ecosystem specific but some are traditionally grown in more than one ecosystem. Through discussions with field staff, leading farmers and rice breeders, tested cultivars were selected against cultivar distinctness. In the high hills, five different landraces collected from varied altitudes were selected. In the mid hills and on the Tarai plain, some 6 to 8 landraces were selected. A list of cultivars, their names and distinct traits is presented in Table 10.1. The most popular improved varieties were included for performance comparison. In the high hills, the improved variety ‘Zhingling 78-102’, introduced by IRRI, was used as a check. In the mid hills, an improved variety ‘Khumal 4’ (‘IR 28’ x ‘Pokhreli masino’) was used. On the Tarai plain, the improved variety ‘Sabitri’ and two widely grown introduced varieties, China 4 and Sona masuli were included. Further descriptions on extent and distribution of cultivars tested are given in Chapter 3.

10.2.3 Research approach

Cultivar performance was assessed using a randomised complete block design replicated three times. The plot size for an individual cultivar was 2 x 3 = 6 m^2 where seedlings were transplanted at a distance of 15 cm x 20 cm. In the upland site, rice seeds were manually sown. The sowing dates, planting methods, input and water management, including weeding, were adopted as per farmers’ practices reported elsewhere (Rana *et al*., 2000). Planting dates varied between locations and rice ecosystems. In the high hills, rice seeds were sown on the 12^{th} of Nepali month *Chaitra* i.e. the last week of March. In the mid hill upland, seeds were sown during the third week of April. 7-8 week old seedlings were transplanted. On the *Tarai* plain, rice seeds for rain fed and lowland were sown during the second and third weeks of June, respectively. On average, 45-55 day old seedlings were transplanted.

Table 10.1 Characteristics of rice ecosystems used for multi-environment experiments at high hill, mid hills and *Tarai* plain study areas of Nepal

Study area / Variables	High hill (Jumla – 2250m)		Mid hills (Kaski - 670-1430m)			*Tarai* plain (Bara - 85m)	
Local ecosystems	*Gadkule*	*Kholapane*	*Ghaiya*	*Tari*	*Sinchit*	*Ucha*	*Nicha*
Literal translation / meaning	Irrigated from glacial sources	Irrigated from stream sources	Un-irrigated upland	Rainfed rice environment	Irrigated rice environments	Rainfed rice environments	Irrigated rice environments
IRRI description	Irrigated lowland	Irrigated lowland	Upland	Rainfed lowland	Irrigated lowland	Rainfed lowland	Irrigated lowland
Source of water	Stream	Glacial	Rainfed upland	Rainfed lowland	Canal	Rainfed	Canal
Soil pH	5.7 - 6.4	6.01	5.364 ± 0.08	5.05 ± 0.01	5.00 ± 0.02	7.49 ± 0.14	7.35 ± 0.11
Organic matter %	2.1 - 4.4	3.4	1.499 ± 0.10	2.19 ± 0.10	2.13 ± 0.19	0.91 ± 0.07	0.06 ± 0.06
Total Nitrogen %	0.07 – 0.16	0.07	0.088 ± 0.00	0.12 ± 0.00	0.11 ± 0.00	0.06 ± 0.00	0.06 ± 0.00
Available Phosphorus ppm	13.9 - 34	15.3	29.24 ± 5.62	17.78 ± 6.19	26.4 ± 12.4	0.91 ± 3.24	7.95 ± 1.09
Available Potassium ppm	89.1 - 296	149.9	62.55 ± 7.54	42.80 ± 3.8	43.21 ± 7.93	56.0 ± 12.9	44.42 ± 1.74
Main soil texture	Sand, Silty loam	Sandy loam	Sandy loam	Sandy loam	Silty clay loam	Sandy loam	Sandy clay loam
Selected cultivars	1. Chumchaur (2800m) 2. Dipangoun (2600m) 3. Lamra (2400m) 4. Raralihi (2200m) 5. Sinja (1950m) **6. Zhingling 78**		• Rato ghaiya	• Mansara • Kathe gurdi	• Jhinuwa • Ekle • Rato anadi • **Khumal 4**	• Nakhisaro • Sathi • Mutmur • Sokan	• **China 4** • Bhati • Kariya kamod • Basmati • **Sabitri** • **Sona masuli**
Cultivar characteristics	• Altitude specific landrace • Cultivated from 1950 - 2800m • Blast susceptible		Specific and popular among other 12 landraces	Specific and widely cultivated.	• Fine& scent • High yielding • Sticky rice.	Widely grown, Sathi with closed panicle.	Grown to water lodging, scent, fine grain

Note: SL=Sandy loam, SCL=Sandy Clay Loam, SiCL=Silty Clay Loam, S= Sandy, SL=Sandy Loam, Underlined figures indicate significant at p=0.01 level of significance, Soil colour and texture as described by Munsell Color Chart (2000), V/C=Value and Chroma as of Munsel colour chart; Bold names are improved varieties.

10.2.4 Observations

Performance was assessed with regard to grain yield, agronomic, phenological, post-harvest and culinary characteristics using rice descriptors (IRRI,1980). Physical measurements were performed on 25 plants per plot, randomly selected. Grain yield was harvested from the net plot area and weighed at 14% moisture content. Rice cultivars were assessed for their grain weight, milling recovery, protein and amylose content.

The post harvest assessment was performed at the Agricultural Botany Division of the Nepal Agricultural Research Council (www.narc.org) and at the Local Initiatives for Biodiversity, Research and Development (www.libird.org), Nepal. At mid hills and on the *Tarai* plain, two independent panels evaluated cooked rice prepared from the rice grain harvested from different ecosystems. A total of 11 female panellists evaluated these samples. These scores were standardized by an equation described by Singh *et al.*, (2001). The panel members graded cooked rice as good (5), moderate (3) or poor (1). To derive preference weight for individual traits, panellists' response was standardized.

weighted mean = (n x 5 + n x 3 + n x 1)/ N, where n stands for responses given by panel members and N represents the total number of panel members:

$$\text{weighted mean} = \sum_{i=1}^{n=N} \frac{5 \text{ x n} + 3 \text{ x n} + 1 \text{ x n}}{\text{N}}$$

At both locations, cooked rice was tasted using common traits which were rated against pre-defined scales. Cooked rice was characterized by appearance, taste, aroma, softness and texture.

10.2.5 Data analysis

The data were analysed using two different statistical tools: a) partitioning of variance through the analysis of variance (ANOVA); and b) principal component analysis. In the ANOVA I used location, ecosystem and genotype as fixed factors and years and error terms as random in a mixed model. A reduced two-way ANOVA model was adopted for data analysis.

$y_{ijk} = m + G_i + E_j + (ge)_{ij} + E_{ijk}$ $i=1\ldots,n;\ j=1\ldots,\ n_e;\ k=1\ldots,\ n_r$

where *m* is the overall mean, G_i is the effect of genotype *i*, *Ej* is the effect of rice ecosystems *j*, $(EG)_{ij}$ is an interaction effect associated with genotype *i* and rice ecosystems *j and* E_{ijk} is the error associated with each measurement. A series of one-way and two-way analyses of variance were performed. Means were compared using Tukey's test: LSDα = (t α 0.05) * SE. The data were analysed using Minitab 13 software (www.minitab.com).

Principal component analyses were performed for qualitative and quantitative data. The data were auto scaled as A / (SDev + B), where A=1.0; B=0.0. PCA was performed several times for qualitative as well as quantitative data. Since the qualitative data showed little contribution to systematic variation, only PCA with agronomic parameters is presented. The first two PCs were plotted and visually observed to determine patterns, clusters, and correlations. The data were analysed using the Unscrambler software package (camo@camo.no) to derive score plots, loading plots and bi-plots.

Two independent test panels tasted cooked rice in the mid hills and on the *Tarai* plain against the same parameters and scales. As for other observations, culinary data were analysed using principal components and the analysis of variance model. The objects and variables were compared with raw data and the ANOVA results.

10.3 Results

10.3.1 High hill agro-ecosystem

Statistical analyses revealed strong differences between ecosystems and genotypes, but the interactions between them were insignificant, except with grain and straw ratio (Harvest Index). Higher grain yields were recorded from plots that were irrigated from stream water sources. Grain yield also varied by individual cultivars. The improved variety produced the highest grain yield under both ecosystems (Table 10.2). There was no genotype x environment interaction for grain yield. This showed that the improved variety performed better in both stream water (‘favourable’) and glacial (‘stressed’) environments. Unlike the improved variety, all landraces produced low grain yield in both ecosystems. Given similar inherent soil nutrients, the lower yields in glacial as opposed to stream water environments were associated with water temperature.

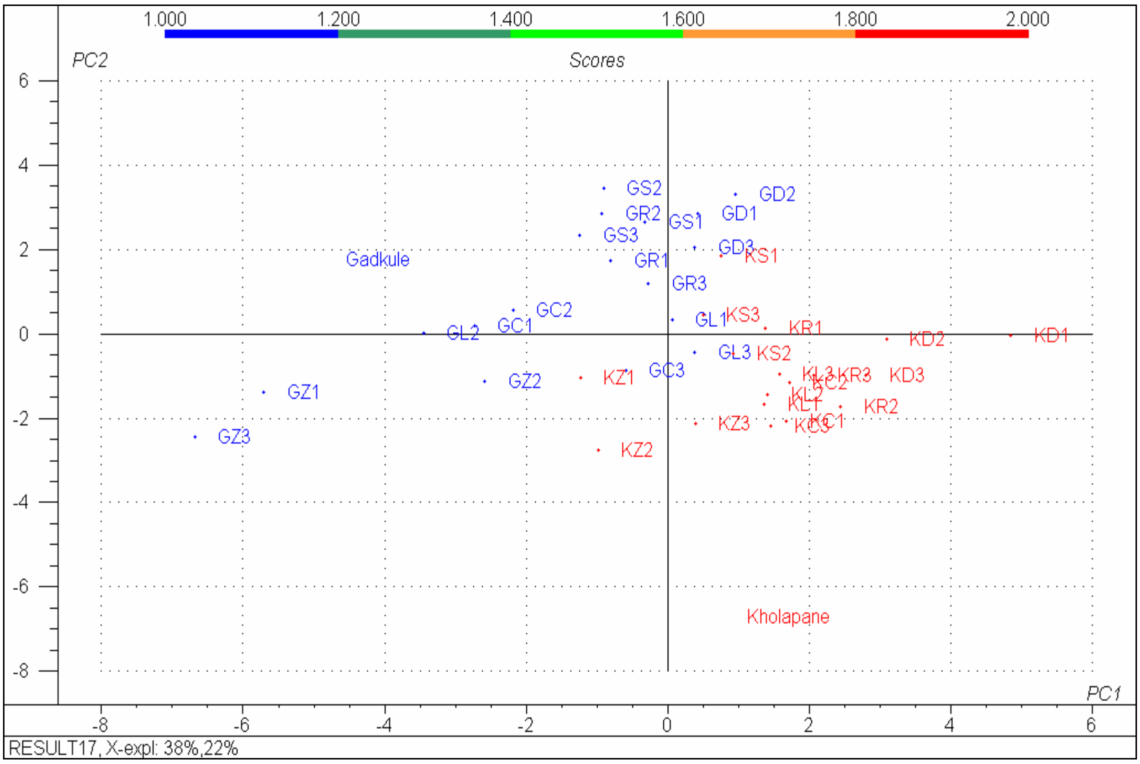
Table 10.2 Flowering days, grain yield (kg/ha) and harvest index measured in two rice ecosystems (*Gadkule* and *Kholapane*) during 2001 at high hill site, Nepal.

Cultivar	Flowering days		Combined analysis	Grain yield		Combined Analysis	Harvest Index		Combined analysis
	Stream	Glacial		Stream	Glacial		Stream	Glacial	
Chumchaur	138	133	136	3876	3219	3548	0.49	0.40	0.45
Dipangoun	138	137	137	2777	1943	2360	0.35	0.30	0.32
Lamra	138	137	138	3765	2998	3381	0.45	0.39	0.42
Raralihi	137	134	136	3135	2764	2950	0.42	0.39	0.41
Sinja	134	130	132	3100	2952	3026	0.34	0.39	0.37
Zhingling 78	134	132	133	4566	3243	3905	0.48	0.48	0.48
Mean				3537	2853	3195	0.42	0.33	0.41
p ecosystem			0.000			0.019			0.051
p cultivar	0.417	0.01	0.000	0.008	0.000	0.000	0.014	0.000	0.000
p cv x eco			0.147			0.159			0.048
LSD				445	298	263	0.05	0.03	0.02

The slight genotype x environment interaction for harvest index needs mentioning. The improved variety had a higher number of tillers per hill, high spikelet density and grain filling which yielded a higher harvest index. The cultivar from the highest elevation Chumchaur (2800m) attained greater plant height, but also produced a larger number of grains per panicle and a high harvest index.

PC1 and PC2 accounted for 60% of the systematic variation. This variation with PC1 was primarily associated with ecosystem more than cultivars.

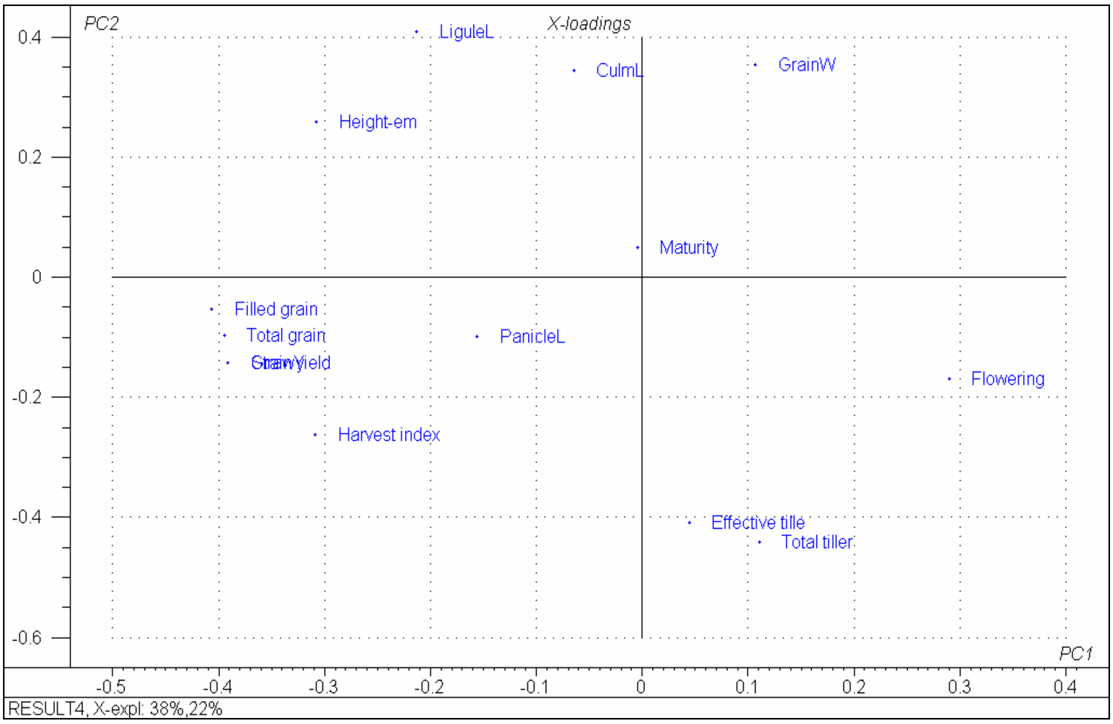
Figure 10.1 Display of objects revealed by PCA from rice experiments conducted at high altitude site, Nepal.



Encoded objects ecosystems: cultivar:observation, First letter denotes cultivar (C=Chumchaur, D=Dipangoun, L=Lamra, R=Raralihi, S=Sinja, Z=Zhingling 78); the associated numbers are replicates.

The quality traits contributed little to the PCs and were excluded from the analysis. Attributes such as grain and straw yield, grain filling, panicle length and harvest index were negatively correlated with flowering time. Height traits and grain weight, effective tiller as well as the the total tiller counts were associated with PC2. Consistently, the improved variety was shorter, earlier and had more tillers, whereas the traditional varieties were taller and had heavier grain weights. Their grain weight decreased when grown with water supplied from glacial sources (Figure 10.2). The cold water caused a greater reduction in grain yield on the improved variety than landraces.

Figure 10.2 Loadings for traits measured from reciprocal experiments conducted in *Gadkule* and *Kholapane* ecosystems at high hill site, Nepal.



10.3.2 Mid hill agro-ecosystem

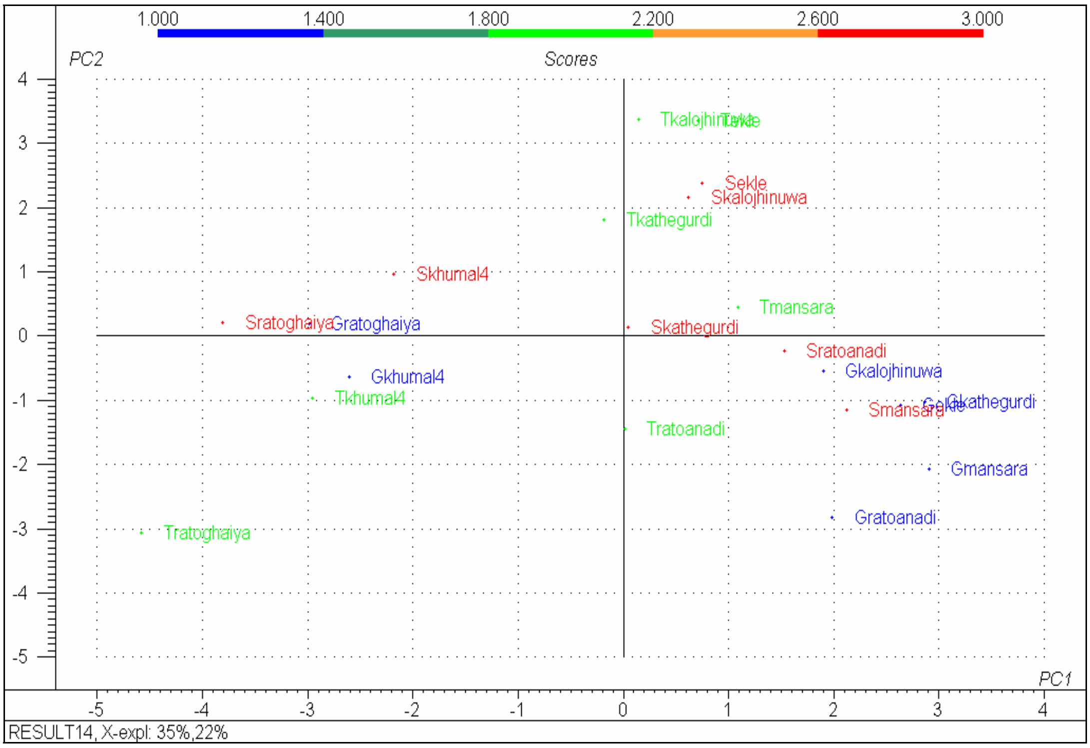
The tested cultivars could be grouped into two maturity classes, early and late. The differences due to years and ecosystems were variable. The difference for flowering and maturity days were highly significant ($p<0.001$) while the difference for grain yield was insignificant. There were strong interactions between ecosystems x years. The most pronounced were the differences in earliness and cultivars ($p<0.001$) although the effects were only consistent with regard to flowering (Table 10.3).

Table 10.3 Flowering and maturity days, grain yield (kg/ha) recorded in rice cultivars tested in field experiments conducted during 2001 and 2002, mid hills, Nepal.

	Flowering days				Maturity days				Grain yield (kg/ha)			
Cultivars	Upland	Rainfed	Irrigated	Combined	Upland	Rainfed	Irrigated	Combined	Upland	Rainfed	Irrigated	Combined
Mansara	152	146	133	144	183	177	166	175	2350	4367	3303	3340
Kathe gurdi	154	146	131	144	188	181	167	178	2751	4367	3179	3432
Kalo jhinuwa	161	153	140	152	193	183	168	181	1981	3528	3247	2919
Ekle	165	155	141	154	194	182	176	184	2192	4618	3953	3588
Rato aanadi	159	152	140	150	187	180	167	178	3127	3035	4356	3506
Khumal 4	109	106	109	108	141	139	149	143	2174	1466	3109	2250
Rato ghaiya	95	93	93	98	126	121	137	128	3068	943	1907	1973
Mean value	142	136	127	136	173	166	161	167	2520	3189	3293	3001
p year	0.638	0.013	0.161	0.060	0.005	0.005	0.161	0.991	0.888	0.618	0.347	0.965
p eco				0.014				0.051				0.273
p cultivar	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.000	0.919	0.000	0.016	0.410
p year x eco				0.000				0.000				0.489
p year x cv	0.000	0.000	0.000	0.905	0.000	0.000	0.000	0.000	0.000	0.179	0.333	0.000
p cv x eco				0.000				0.000				0.000
LSD				8				9	262	425	358	344

All the landraces were found to be photoperiod sensitive. The landraces from irrigated ecosystems matured latest while the upland landrace (Rato ghaiya) and the improved variety (Khumal 4) matured early. Although irrigated rice landraces were sown late, all attained their flowering stage only when the day length shortened. In contrast, the upland rice landrace flowered early when the day length was still long, regardless of sowing date. Unlike the improved variety, all landraces grown under irrigated ecosystems attained taller plant height and produced higher straw yield.

Figure 10.3 Display of objects revealed by PCA from rice experiments conducted under upland, rain fed and irrigated ecosystems in the mid hills, Nepal (2001-2).



Combined analysis revealed no difference in average grain yield due to year, ecosystem, cultivar or year x ecosystem ($p<0.05$). However, there were strong interactions between year x cultivar as well as ecosystem x cultivar ($p<0.001$). On average, the grain yield differences between ecosystems were low. However, cultivar performance differed by ecosystems. Cultivar performance in the upland was insignificant. The performance of the sticky rice landrace (Rato anadi) was as good as the upland landrace (Rato ghaiya). On the other hand, the improved variety (Khumal 4) produced a low yield. The cultivar x year interaction was due to later sowing in 2002, which tended to reduce yield, particularly for landraces that mature late as opposed to those that mature early, 'Rato ghaiya'[1], and the improved variety

[1] 'Rato ghaiya' that is grown under upland condition was found sensitive to shorter day length and therefore flowers when days are still long. Unlike main season rice landraces, which were sensitive to long day length, 'Rato ghaiya' flowered and matured earliest though it was sown as late as main season rice.

that is day neutral. Hence, this interaction showed the early group to be more stable in situations of delayed sowing.

In rain fed conditions, cultivar performances were significantly different $p<0.000$). The late maturing good quality rice landraces were superior to both early maturing cultivars, irrespective of origin (Rato ghaiya, Khumal 4). The yields were highest of all water management conditions, but depressed especially among early maturing cultivars.

In the irrigated ecosystem, the late maturing landraces were again superior on yield, but 'Khumal 4'[2] performed relatively better than the early upland landrace. The landraces 'Rato anadi' and 'Ekle' were superior while the upland landrace was below average. The rain fed landraces (Mansara, Kathe gurdi) gave average grain yield. The upland landrace, 'Rato ghaiya' produced the lowest grain yield (Table 10.3). Compared to the irrigated ecosystem, a greater harvest index (HI) was obtained from rain fed. Compared to early maturing cultivars, a higher HI was recorded for late maturing landraces grown in the irrigated ecosystem. The early maturing cultivars gave a higher HI when grown in the irrigated ecosystem (Figure 10.4).

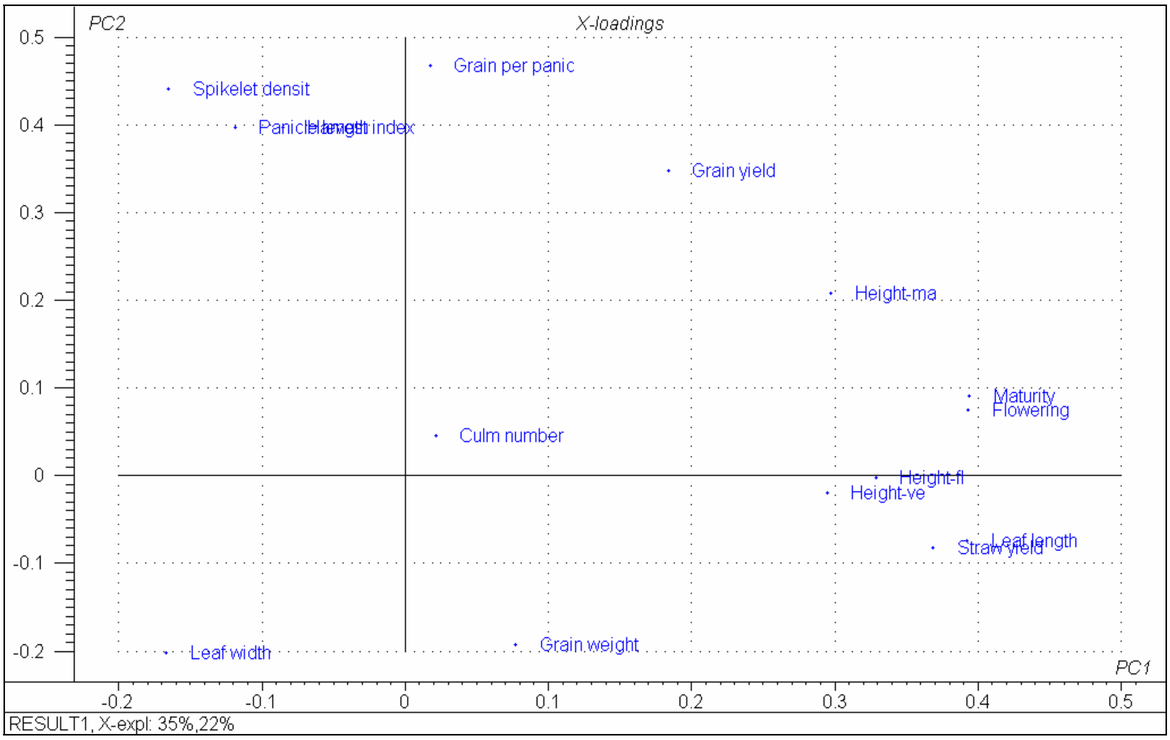
PCA explained 57% of the systematic variation when analyzed with 15 different yield attributes. The cultivars formed different clusters. The early maturing (left quadrant for early and right for late) cultivars accounted for the variation along PC1 (Figure 10.3). PC2 distinguished principally according to yield, grain per panicle and grain weight. The upland landrace showed a high degree of interaction with ecosystem; performance was reduced when grown in irrigated ecosystems. The landraces from rain fed areas out-yielded all tested

[2] Improved variety recommended for irrigated ecosystems throughout the mid hills

cultivars in their traditional habitats but their yield reduced especially when grown upland. The performance of ‘Rato anadi’, traditionally grown in fertile soils with irrigation decreased when grown in rain fed or upland ecosystems.

Most yield attributes clustered along PC1, which was accounted for by flowering and maturity days, plant height, straw yield and leaf length. Flowering and maturity days showed strong correlations. The tall varieties that mature latest produced heavier straw yields as opposed to those that matured early and counted fewer numbers of tillers (Figure 10.4). The landraces with fine and smaller grains, such as ‘Kalo jhinuwa’ and ‘Ekle’, had a greater number of grains per panicle. In contrast, the landraces Rato anadi and Mansara with coarse grain had less grain count. In PC2, greater variation was accounted for spikelet density, panicle length and harvest index. These parameters correlated positively with early maturity. Most quality traits were distributed towards the PC coordinates origin and do not affect the pattern.

Figure: 10.4 Loadings plot for yield attributes revealed by PCA in rice experiments, Kaski, Nepal.



The performance of all cultivars, especially the late ones, was reduced when grown in a stressed environment. In contrast, cultivar performance greatly varied when grown in more favourable environments. Cultivars from favourable environments that also mature late grow more widely than the early maturing ‘Khumal 4’ and ‘Rato ghaiya’, grown in a stressed environment (upland). In other words, differences between cultivars are narrowed when grown in stressed environments.

The performance of the genotypes tested differed by individual ecosystems. In upland, earliness is clearly favoured when neither late landraces nor the early maturing improved variety are able to reach their yield potential. In rain fed conditions, late maturing genotypes were favoured over those that mature early. On average, performance of native landraces was good under rain fed conditions. Surprisingly, 'Ekle' coming from irrigated ecosystem out-yielded them all when grown under rain fed ecosystem. In the irrigated ecosystem, the inferior performance of the early maturing upland landrace is evident. In spite of the differences in maturity duration (17-19 days), 'Khumal 4' matches upland landrace, but not the landraces from rain fed or irrigated ecosystems. This shows that there are tendencies towards adaptive differences among the landraces. Earliness as a response to water deficiency which particularly is clear in the upland, whereas the responses in rain fed and irrigated ecosystems do point to a differential adaptedness of landraces to their respective habitats.

10.3.3 *Tarai* plain agro-ecosystem

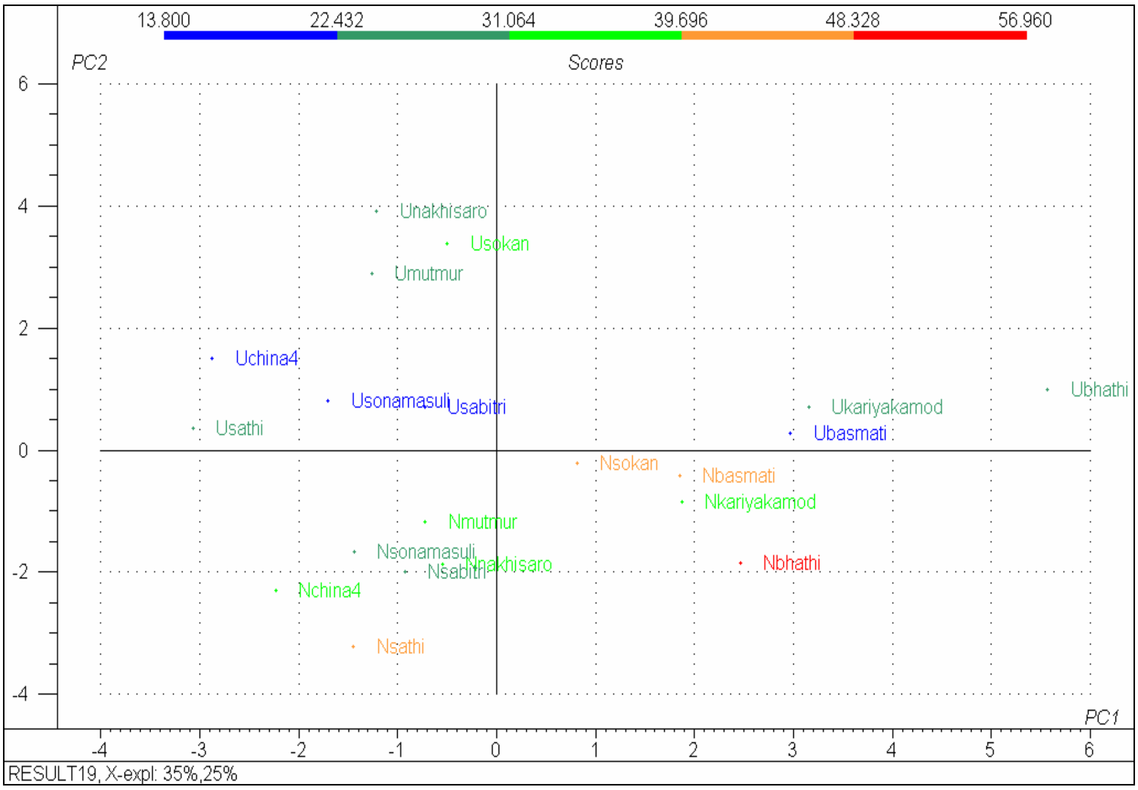
Results from ANOVA showed that grain yield differences for ecosystem and cultivar x ecosystem interaction were significant ($p<0.001$). The higher grain yields were obtained from rain fed crops (Table 10.4). Some out-yielding cultivars in rain fed conditions also produced higher yield when grown irrigated. In terms of maturity duration and plant height, cultivars can be grouped into three categories: 1) the improved and introduced varieties that mature early and attain short plant height; 2) the landraces that are medium maturing and attain tall plant height; and 3) the late maturing, tall with fine grain and aromatic landraces. Unlike the improved and introduced varieties, the performance of rain fed landraces was inconsistent.

Table 10.4 Flowering, maturity days and grain yield (kg/ha) measured in field experiments conducted in rain fed (*Ucha*) and irrigated lowland (*Nicha*) ecosystems on the *Tarai* plain, 2002.

Cultivars	Flowering days		Combined analysis	Maturity days		Combined analysis	Grain yield		Combined analysis
	Rainfed	Irrigated		Rainfed	Irrigated		Rainfed	Irrigated	
Nakhisaro	78	97	88	104	124	114	5191	2581	3886
Sathi	68	93	81	97	124	110	3590	1563	2576
Mutmur	71	93	82	97	124	110	4585	2573	3579
Sokan	73	97	85	97	124	110	3856	1062	2459
China 4	74	97	86	99	124	112	3953	2345	3151
Bhathi	133	137	135	165	165	165	1797	1919	1858
Kariya kamod	137	140	139	163	163	163	2350	1828	2089
Basmati	154	136	195	162	162	162	2536	2411	2473
Sabitri	112	128	119	142	159	151	3454	2400	2927
Sona masuli	113	128	120	142	157	150	4534	2989	3762
Mean	101	115	113	127	143	135	3585	2167	2876
p ecosystem			0.817			0.002			0.002
p cultivar	0.074	0.000	0.066	0.000	0.000	0.000	0.000	0.002	0.164
p cultivar x eco			0.277			0.000			0.000
LSD	32	8	15	12	8	7	484	281	322

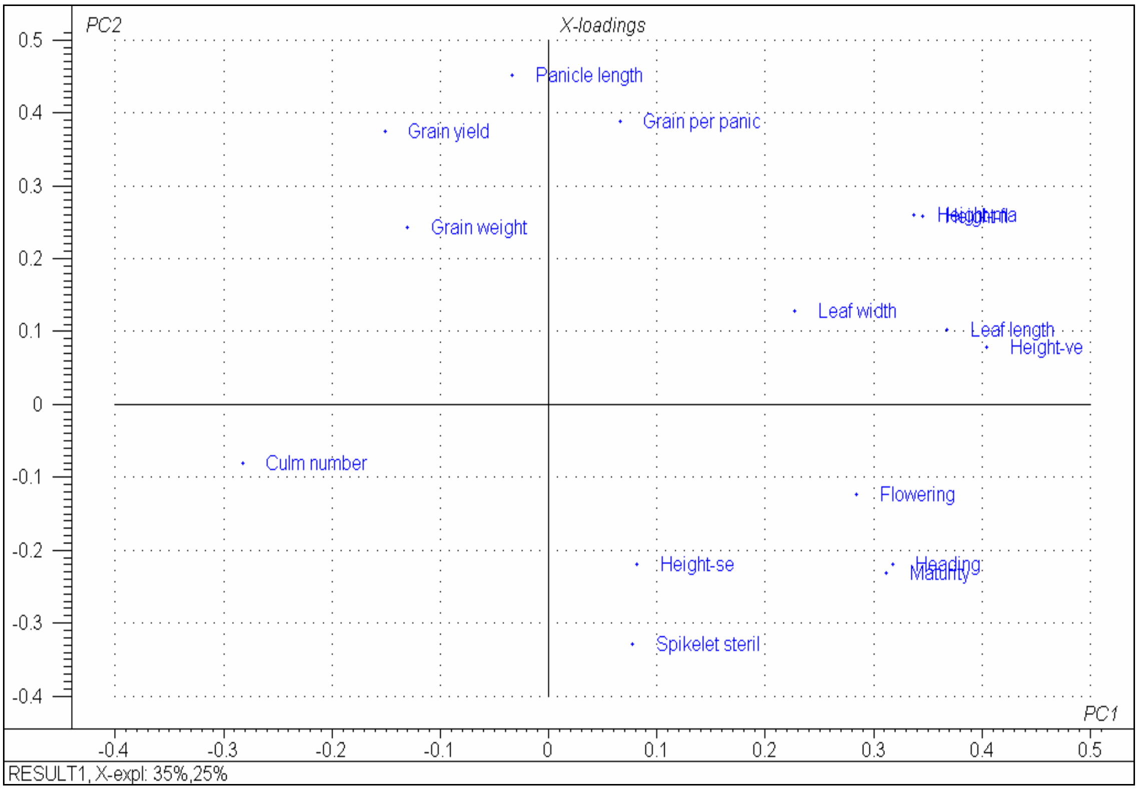
PC1 and PC2 (Figure 10.5) together describe 61% of the total variation. The PC1 mainly displayed differences in maturity duration (early, medium and late) and plant height, while PC2 largely displayed the grain yield differences. Most landraces from irrigated ecosystems distributed towards PC1, while those from rain fed towards PC2. The improved varieties ‘Sona masuli’ and ‘Sabitri’ grown rain fed spread close to the PC coordinate origin. Landraces from rain fed origin such as ‘Mutmur’, ‘Sokan’ and ‘China 4’ accounted for the greater variation in PC2. The landraces ‘Bhati’, ‘Basmati’ and ‘Kariya kamod’ differed from others (Figure 10.5).

Figure 10.5 Scores plot revealed by PCA from rice experiments conducted in Ucha and Nicha on the *Tarai* plain, Nepal.



Plant height and grain fertility distributed along PC1. Grain yield, grain per panicle, panicle length, grain weight and leaf width contributed greater variation towards PC2 (Figure 10.6). Similarly, panicle length, grain per panicle, grain weight, and grain yield showed strong positive correlations. The days to booting, flowering and maturity showed strong correlations, which also correlated with grain fertility.

Figure 10.6 Loading plot revealed by PCA from rice experiments conducted in rain fed and lowland ecosystems on the *Tarai* plain, Nepal.



10.3.4 Effects of ecosystem factors on post-harvest characteristics

There were only minor differences between genotypes cultivated in mid hills and on the *Tarai* plain as far as post harvest characteristics are concerned. The mid hill landraces, however, differed in terms of grain weight, grain length, grain shape and kernel elongation as well as amylose, protein and ash contents ($p<0.05$). The landrace from the irrigated ecosystem (Rato anadi) produced the heaviest grain weight (22g per 100 grain), while the fine and aromatic rice landrace (Kalo jhinuwa) produced the lightest (Table 10.5). The amylose content was similar for all cultivars, except for a sticky rice landrace (Rato anadi), which had the lowest (5.0). On the *Tarai* plain, cultivars differed according to grain length, water absorption capacity, and amylose content ($p<0.05$). The ecosystem factors affected some post-harvest characteristics: effect on amylose content was barely significant ($p<0.06$) with the only sticky rice (Rato anadi) included at mid hill rice experiment. Cooking quality of Chinese rice studied it was documented that environment could affect the gene expression of the maternal plant in opposite ways to the amylase content (Shi *et al*., 1997). Other researchers, however, found that environment factors can significantly modify gene expression, especially those that governs the amylase content. Chen and Zhu (1999) studied genetic effects genotype x environment interaction for cooking quality of Indica-Japonica (*Oryza sativa* L.) crosses of rice and found that environment factors enhances the expression of dominant genes, without changing their directions. These research results agree with findings elsewhere.

Table 10.5 Post harvest characteristics of rice grain produced under field experiments conducted across rice ecosystems in high hills, mid hill, and *Tarai* plain sites of Nepal.

Ecosystem and Cultivar	1000 gr.wt.(g)	Milling %	Grain length (cm)	Grain shape	Water absorption	Kernel elongation	Amylose Content %	Protein %	Ash %
Jumla, High hill									
1.1.Chumchaur	20.8	73	5.8	2.02	2.61	1.88	19.9	8.810	0.39
1.2. Dipangoun	19.3	70	5.9	2.12	2.66	1.94	23.6	8.410	0.49
1.3. Lamra	21.4	71	6.13	2.16	2.73	1.9	20.6	9.000	0.44
1.4. Raralihi	21.4	72	5.55	1.99	2.65	1.55	20.6	8.940	0.39
1.5. Sinja	20.3	71	5.51	1.99	2.96	1.94	20.6	8.590	0.40
1.6. Zhingling 78	20.8	70	5.63	2	2.73	1.96	25.2	8.700	0.37
P cultivar	0.825	0.277	0.556	0.037	0.710	0.692	0.837	0.588	0.38
P ecosystem	0.840	0.363	0.119	0.005	0.650	0.837	0.148	0.779	0.57
Kaski, Mid hill									
2.1. Mansara	17	69	5.6	2.31	2.99	1.84	26.6	8.25	0.34
2.2. Kathe gurdi	16	71	4.5	1.71	3.01	2.1	21.6	7.44	0.46
2.3. Kalo jhinuwa	11	72	5.3	2.83	3.31	1.78	22	7.71	0.39
2.4. Ekle	12	70	4.2	1.7	3.15	2.02	22.6	7.59	0.37
2.5. Rato anadi	22	67	5.6	2.04	3.44	2.22	5	6.98	0.31
2.6. Rato ghaiya	16	68	5.1	2.03	3.02	1.97	24.4	8.74	0.59
P cultivar	0.00	0.25	0.00	0.00	0.06	0.00	0.00	0.02	0.00
P ecosystem	0.04	0.97	0.01	0.03	0.09	0.04	0.06	0.54	0.08
Bara, *Tarai* plain									
3.1. Nakhisaro	16	68	5.3	2.3	3.1	1.64	24	8.07	0.35
3.2. Mutmur	17	63	5.4	2.3	3.7	1.44	23.2	8.23	0.33
3.3. Sokan	19	66	5.6	2.3	3.1	1.69	24.8	8.24	0.39
3.4. Bhathi	15	69	5.8	2.7	3.6	1.73	19.7	8.06	0.32
3.5. Basmati	14	65	5.5	2.5	4.4	1.48	27.4	7.77	0.32
3.6. Sona masuli	17	66	5.2	2.1	3.5	1.33	31.2	7.63	0.39
P cultivar	0.39	0.74	0.03	0.11	0.00	0.49	0.02	0.80	0.52
P ecosystem	0.61	0.83	0.63	0.93	0.11	0.25	0.73	0.50	0.64

Note: 1=High hill; 2=Mid hills; 3=*Tarai* plain; Seed samples analysed at Agriculture Botany Division, Khumaltar, NARC, Nepal and LI-BIRD, P O Box 324, Pokhara, Kaski Nepal.

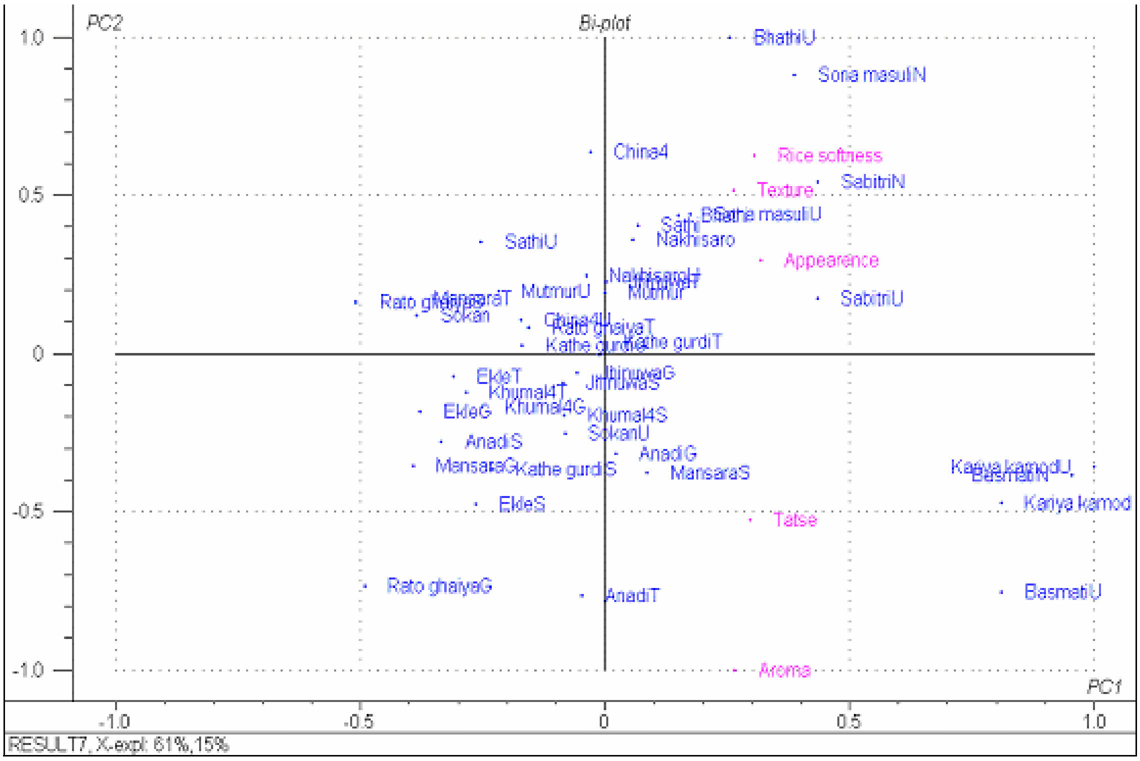
10.3.5 Panel assessment of cooking quality characteristics

The results of ANOVA revealed that ecosystem factors influenced taste ($p<0.09$), aroma ($p<0.04$), and texture ($p<0.07$), but not appearance. The ecosystem factors affected amylose content ($p<0.1$). An overview of panel assessment of culinary traits is presented in Plate 1.

PC1 and PC2 explain a 76% systematic variation (Figure 10.7). The taste and aroma distributed towards PC1, whereas softness, texture and appearance distributed along PC2. Most of the entries from the mid hills appear less distinguishable according to growing environments. However, the most distinguished ones were those from the *Tarai* plain. The *Tarai* plain landraces 'Kariya kamod' and 'Basmati' were the most distinct in PC1 compared to the improved varieties, which clustered towards PC2. The landraces 'Kariya kamod' and 'Basmati' strongly correlated taste and aroma, but rated poorly with respect to softness, texture and appearance. The improved and introduced varieties positively correlated with respect to softness, appearance and texture (Figure 10.7).

The eating quality of cooked rice improved especially with cultivars from stressed environments (e.g. upland, rain fed) that have coarse grain and does not produce aroma were grown under more favourable environments (e.g. lowland). This shows that some traits that determine eating quality in rice are affected by environment factors. The laboratory analyses for post harvest characteristics showed that ecosystems significantly affect grain weight, grain length, grain shape and kernel elongation ($p<0.05$) and the effect on amylase content was barely significant ($p<0.06$). The ecosystem factors, however, had no significant effects on milling recovery, protein or ash content (Table 10.5). As reviewed earlier these results agree with previous research findings.

Figure 10.7 Bi-plot revealed by PCA for culinary traits of cooked rice prepared from grains produced at variable environments upland, rain fed, irrigated (mid hills) and rain fed and lowland (*Tarai* plain), Nepal.



Last Suffix capital letters denote ecosystems: U-Ucha, N-Nicha, G-Ghaiya, T-Tari, S-Sinchit

10.4 Discussion and conclusions

10.4.1 High-hill agro-ecosystem

The performance differed for cultivars reciprocally grown on the two ecosystems, distinguished by water temperature. Results show that cultivar adaptations are determined by water temperature. The improved variety out-yielded all landraces tested on both ecosystems: the improved variety grows better across different ecosystems than landraces. Apart from superior agronomic performance the improved variety was relatively free from rice diseases. Low yield of landraces could also due to infection of neck and leaf blasts. The landrace from

Chumchaur flowered slightly earlier when grown with glacial melt water. To some extent, cultivars that flower early escape cold injury. The improved variety was formally released in the high hills for its high yield and cold tolerance characteristics (NARC, 2002).

The complexities of ecological conditions to which rice is adapted, especially the breadth of hydrological conditions, indicate that great variability of water related adaptations exists within the germplasm (Toole and Chang, 1979). The effects of chilling injuries were observed on maturity duration, panicle length, grain weight and harvest index. Grain filling was also affected by chilling temperature. Chilling caused by air or water temperature affects rice growth at any stage. Chilling at the seedling stage is often related to low water temperature while chilling at the flowering stage is often related to cool air temperature. Sthapit (1994) describes two types of chilling that occur in Nepal: i) the delayed-type, prevalent at lower elevations; and ii) the sterile-type, prevalent at higher elevations. To prevent chilling caused mainly by low water temperature, Jumla farmers i) sow rice seeds after the 12th of *Chaitra* (late March) when the water temperature is above 1°C; and ii) re-route water if their rice crop must be irrigated from glacial sources; in the Nepalese hills, water is retained on the terrace and not allowed to flow continuously from one field to another in order to accumulate heat during day-time (Whiteman, 1985 cf. Sthapit, 1994).

The results show no strong evidence that soil nutrients caused the above difference. The grain-filling rate is the most sensitive trait in rice and hence could be used as an indicator of cold tolerance. The plant height and panicle lengths also could be used as indicators of cold tolerance (Luyuan *et al*., (1999). Our studies show, however, that glacial water affects flowering days, plant height, culm length, total and effective tiller counts, panicle exsertion, spikelet density, grain filling, grain weight, including grain and straw yields. Thus, the high altitude rice suffers not only from the sterile-type of chilling that occurs at high altitude (Sthapit, 1994), but also from the delayed-type of chilling at various stages of crop growth.

10.4.2 Mid hills agro-ecosystem

Cultivar productivity under lowland rain fed was different than upland or irrigated ecosystems. This difference could be due to several reasons, including edaphic factors. Productivity could be related to low levels of phosphorus and potassium (Table 10.1). Regardless of inherent nitrogen and organic matter content, productivity is dependent on soil moisture availability. Hence, well-distributed rainfall determines rice productivity over erratic or intensive nature especially rice grown under upland or rain fed environments.

The upland landrace out-yielded all cultivars on their traditional habitat. The landrace produced greater yield (than upland) under irrigated ecosystem which was still much lower than for other cultivars. Similarly, landraces from rain fed origin performed better in their traditional habitat, but their yield level was decreased in irrigated ecosystems. However, landraces from irrigated ecosystems out-yielded when grown on rain fed ecosystem. Moreover their grain yields in upland were recorded as ‘above average’. Despite delayed maturity, this study showed that some landraces from irrigated ecosystems perform better when grown in rain fed upland. In contrast, landraces from rain fed lowland were negatively affected when grown under irrigated ecosystem. Surprisingly, one landrace grown on the irrigated ecosystem (Rato anadi) consistently produced good yield across all ecosystems, while the improved variety, recommended for irrigated ecosystems (Khumal 4) produced a low yield across all ecosystems. The parents of ‘Khumal 4’ originally come from warmer environments and probably do not contain the necessary adaptive characteristics.

Some landraces from favourable environments[3] (Ekle, Rato anadi and Kathe gurdi) out-yielded the improved variety even in stressed environments (Upland and lowland rain fed). Unlike all tested cultivars belonging to Indica rice, 'Rato anadi', which is characteristically similar to Japonica, showed wide adaptation. Glaszmann *et al.*(1990) reported that Japonica rice cultivars show a high degree of cold tolerance, whereas the degree of cold tolerance of Indica rice was moderate to low. In terms of resource use, Japonica types were more efficient than Indica types. The same landrace yielded heavier straw yield as well as taller plant height when grown in a non-traditional ecosystem. The effects of ecosystem factors on most post-harvest, culinary and bio-chemical contents were insignificant. This research results agree with the findings of Oka and Chang (1964) and show wide adaptation. This research results can have different implications to farmers' management of diversity on-farm.

Unlike farmers' practice of cultivating ecosystem specific landraces, this research results showed that some landraces traditionally grown under irrigated ecosystem grow successfully away from their traditional habitats such as upland and lowland rain fed. The performance of landraces traditionally grown under upland and rain fed was significantly lower than native landraces when cultivated under irrigated ecosystem. Introduction of more adapted landraces especially to ecosystems where variety choice is limited (e.g. uplands and rain fed) provides direct benefits to farmers by;

- increasing variety choice that ensures greater economic and biological returns from high quality rice varieties

[3] Rice ecosystems are broadly divided into 'stressed' and 'favorable' in relative and contextual terms. In the high hills, stress is caused by low air or water temperature. In mid hills and on the *Tarai*, stresses are caused by inadequate moisture and / or fertility. Contrary to this, rice environments better with respect to irrigation, fertility and water or air temperatures are considered 'favorable'.

- increasing diversity so reducing risk of crop failure
- evacuating more favourable environments (irrigated ecosystems) currently occupied by low yielding landraces for high yielding improved varieties but not at the expanse of high quality rice varieties
- shaping and reshaping biodiversity with the introduction of high yielding varieties

HOWEVER, the prospective landraces suggested above for stressed environments are sensitive to longer day length and their direct introduction to stressed environments (especially upland) where rice landraces sensitive to shorter day length are traditionally cultivated would be constrained. To cope this problem following options are suggested:

i) experiment to determine appropriate planting dates along with their implications on the existing cropping patterns

ii) include these potential landraces to develop photoperiod insensitive varieties that otherwise resemble the same agronomic traits

10.4.3 *Tarai* plain agro-ecosystem

Greater productivity was associated with good access to irrigation water, soil nutrients and good soil physical properties. The introduced varieties produced heavier grain yield when grown rain fed, considered a more favourable environment (than canal irrigated ecosystem) when receives a well distributed rain fall or irrigation from tube-well pumps. Rana (2004) reported that farmers perceived that irrigated ecosystems are more productive than rain fed ecosystems. This research results, however, showed that productivity was higher in the rain fed ecosystem rather than an irrigated ecosystem. Laboratory analysis showed that rain fed soils contain higher levels of available soil nutrients than in the lowland ecosystems.

Joshi *et al.,* (1999) reported that landraces are tall, low yielding and susceptible to lodging and therefore are grown with low inputs. The research results revealed, however, that some landraces, particularly those from favourable environments, grew better even in stressed environments. The tested cultivars could be grouped into three maturity classes. The landraces from the irrigated ecosystem mature latest while those grown under rain fed were medium maturing. All improved and introduced varieties matured earliest. Unlike the improved and introduced varieties, which were day-neutral, all landraces were found to be photoperiod sensitive; maturity duration varies according to the time of transplanting.

10.4.4 Comparative performance

In terms of performance, cultivars can be grouped into three broad categories: a) cultivars that perform well only in their traditional habitat; b) cultivars that perform well in their traditional habitats and in closely related environments; and c) cultivars that perform well across rice growing environments. Unlike the earlier reports that showed improved varieties performed better, especially under favourable soil nutrients and water regimes, this study showed some improved varieties performed equally well or even better also under stressed environments, while some landraces out-performed some improved varieties, even in more favourable environments. On the basis of performance, the traits studied could be grouped into four categories:

- i) critically important traits such as cold tolerance, response to day length
- ii) economically important traits including grain yield, yield attributes
- iii) post harvest and culinary traits and
- iv) preferable agro-morphological traits, less affected by ecosystem factors.

This study identified cold tolerance and photoperiod sensitivity as key adaptive traits. Grain yield and yield attributes are affected by ecosystem factors. From this study, it can be concluded that rice landraces i) from favourable environments perform equally well or better in moisture and/or fertility stressed environments; ii) those from moisture stressed environments perform relatively poorly in favourable environments; and iii) grow across a wide environments are consistent and stable though they produce relatively lower yields. Unlike the improved or introduced varieties, which are day neutral, landraces were all found to be photoperiod sensitive. Hence, cultivar response to day length was the key adaptive parameter which determines cropping period. Although most landraces grow better in their traditional habitats, some landraces especially developed under favourable environments could grow away from their traditional habitats. This knowledge will enhance decision-making process in research, extension, conservation and livelihoods.

Map: 10.1 Map showing rice production systems across study areas, Jumla, Kaski and Bara.

Rice production at Jumla high altitude site (2250m)

Rice production at Kaski mid altitude site (1150m)

Rice production on the *Tarai* plain (85m)

CHAPTER 11: MAIN FINDINGS AND THEIR IMPLICATIONS TO LIVELIHOODS AND BIODIVERSITY CONSERVATION ON-FARM

In this chapter the main research findings and their implications to the management of crop diversity on-farm are presented. These concern diversity assessments and farmers' ecological, as well as botanical knowledge associated with taro and rice. The experimental results of taro and rice assessed at different temperature and moisture regimes are highlighted. The scientific bases of farmers' knowledge are discussed. The increased awareness of the validity of farmers' knowledge and its importance to livelihood and biodiversity conservation on-farm are discussed.

11.1 Diversity exists but the extent is different in different ecosystems

The amount of diversity was found to be different under different agro-ecological zones and ecosystems within the same zone. The highest amount of diversity was found in the mid hills followed by *Tarai* plain and high hills. Unlike the small scale cultivation of rich taro diversity in the mid and high hills, the *Tarai* farmers grew only a few varieties and at large scale (Chapter 2). The rich taro diversity in the mid hills was associated with factors related to ecosystem, food traditions and local adaptation (Chapters 2 and 5).

As with taros, the number of rice varieties in the mid hills was always higher than on the *Tarai* plain. The distribution of this diversity was related to natural and socio-economic factors. The diversity was also related to food and cultural traditions. The higher number of varieties was maintained under traditional farming systems where farmers' access to inputs, improved seeds and irrigation is minimal. The number of rice varieties maintained was different across ecosystems. The distribution of diversity is described by rice environments, distinguished by the access to irrigation water, soil nutrients and soil physical properties. The number of varieties cultivated under favourable environments was always higher than under stress environments. The reasons for the maintenance of rich diversity under favourable environments were different for individual study areas. Richer diversity on the *Tarai* plain was due to improved access of farmers to a large number of improved varieties together with landraces cultivated for their special uses or localised adaptation. In the mid hills, the maintenance of rich diversity under more favourable environments was associated with i) the cultivation of improved varieties, ii) farmers' continued use of landraces that still are competitive, iii) farmers' choice of landraces that have desired food quality or cultural values and iv) cultivation of introduced varieties. It is also clear that more landraces are grown in the stressed environments. However, farmers restructure diversity based on variety performances and their changing needs. Hence, the maintenance of diversity is affected by several factors related to ecosystem, farmers' choice of varieties, and local needs and preferences.

Developmental interventions have resulted in the expansion of irrigated areas and increased use of external inputs, including modern seeds. Since not all upland is suitable for irrigation, farmers continue with traditional farming systems. Other rice ecosystems survive in both study areas. Therefore, farmers' knowledge about the diversity of rice ecosystems persists, and the rice varieties suited to various rice ecosystems and niches also persist. Farmers maintain localised knowledge and know about varieties they have been growing. However, farmers do not know if particular traits could have prevented the expansion of a variety away from its traditional habitat.

11.2 Farmers describe and measure adaptation

Taro growers listed several descriptors through which they characterise and distinguish varieties that are maintained on-farm. The number of descriptors differed for different study areas and increased with the number of varieties grown. For example, the mid hill farmers recalled greater number of descriptors where the numbers of varieties grown were also high. The common and location-specific preferred traits were recorded in all study areas.

Farmers describe adaptation with respect to the relative performance of individual traits and/or cultivars. Farmers stated that some descriptors define adaptation better than others. Taro farmers elaborate adaptation with respect to key traits such as acridity, plant pigmentation, plant height, corm and cormel size, taste, tuber yield and the number of shoots per plant. Taro varieties are considered adapted when their performance remained the same or improved when grown away from their traditional habitats. Similarly, rice farmers described adaptation based on the performance of some key descriptors. Although rice farmers listed several descriptors, some key traits mentioned were tiller counts, response to day length, grain fertility, plant height and grain yield per unit of land.

Chapter 8 show several descriptors through which farmers determine diversity, local uses, as well as measure adaptation. Although the number of farmers' descriptors varied by study area and ecosystem farmers listed similar descriptors across all ecosystems. In the mid hills, 26 such descriptors were listed but only 11 on the *Tarai* plain. A larger numbers of descriptors were recorded by farmers cultivating rice in moisture stressed environments (e.g. Kaski) compared to farmers cultivating in favourable environments (e.g. Bara). The importance given to individual traits differed by study area and by ecosystem. Farmers' preferences are determined according to their local needs and variety options available to them. These selections are determined by farmers' access to external inputs, irrigation facilities, the importance of crop residues (e.g. straw) in the local farming system and technological options available to farmers (e.g. a threshing machine). This clearly shows that farmers hold rich knowledge adaptable to local conditions.

11.3 Local knowledge distantly relates to the scientific literature

Farmers describe ecosystems and soils based on the observable as well as measurable parameters. In most instances farmers assess soil quality with indirect measurement such as grain yield. Farmers distinguish ecosystems using parameters that have practical significance. Further details are described below.

11.3.1 Ecosystem descriptions

Farmers' descriptions and subdivision of rice ecosystems do not exactly corroborate with that in the scientific literature. Farmers characterize ecosystems according to factors that clearly affect rice crop performance in their environment, such as i) the availability and source of irrigation water (e.g. stream, glacial), and ii) the location and the level of individual rice fields relative to irrigation canals. These environments are further characterised in terms of the soil's water retention capacity and ease of ploughing, and the prevalence of weeds, in order to estimate soil quality and productivity potential. Farmers' descriptions of ecosystems were also found different between study areas. Although farmers consistently referred to similar parameters at the higher level, their descriptive units were found to be different at the lower level such as soil colour. On the other hand, researchers describe rice environments primarily based on the availability of irrigation water and characterise further with physical and chemical property parameters. This research clearly shows that farmers describe ecosystems using parameters that have practical significance.

11.3.2 Farmers' descriptions of soils

Farmers' perceptions of soil fertility and land productivity differed from fertility as assessed by laboratory analysis. The amount of soil nutrients was higher in soil from rain fed compared to soil from irrigated land (Chapter 4). The soil texture that farmers considered most fertile was sandy loam, which has lower water and nutrient holding capacity. These soils become productive when water is properly managed. Despite higher water holding capacity lower productivity with fine textured soils could be linked with lower availability of soil nutrients. These inconsistent results are dependent on the ways soil fertility is described. The farmers predict soil fertility based on 'actual productivity and ease of cultivation or rooting' in a given management regime, while the researchers actually measure potential mainly based on the availability of the individual soil nutrients.

Farmers classify soils according to observable parameters while the soil scientists use a three-dimensional (width, length, and depth) study of soils based upon pre-determined indices, such as the description of pedons in US soil Taxonomy (Brady, 1990). The scientists further characterise soils by morphological and chemical attributes and classify based on theories of soil genesis.

Unlike a scientist's assessment of soil fertility, farmers express soil fertility in relative and contextual terms using several indicators.

Local knowledge provides practical insights, while scientists often create deeper but disaggregated knowledge. Although farmers and researchers agreed especially on higher level descriptors (texture, colour, fertility) disagreements still remained at the lower level. An integrated knowledge of soil productivity indicators and site specific identification of limiting factors would increase the correspondence between scientists and farmer's understandings and help better address the actual soil-related problems at the community level. Integration of local ecological knowledge may enrich science and also enhances agricultural biodiversity on-farm.

11.4 Variety names distinguish diversity

Farmers distinguish crop diversity with names. Farmers create names after distinctive variety traits especially for traditional varieties whereas the improved and introduced cultivars are recognised by names came along with the planting materials. The ways farmers distinguish diversity of taro and rice with names are described below.

11.4.1 Farmers distinguish taro diversity with names

Local names are used to distinguish and estimate taro diversity. As presented in Chapters 5 and 6, the existing diversity is characterised by traits important in ecological, economic or culinary terms. Farmers cultivating many varieties used a large number of descriptors and vice versa. In comparison with the *Tarai* plain, the mid hill farmers listed a greater number of descriptors which corresponded to richer diversity. It appears that farmers managing more diversity have more botanical knowledge.

Similar descriptors were used by farmers in all study areas, whilst some also were location specific. Farmers distinguish diversity by names created after distinctive traits. When the primary name does not adequately distinguish diversity, farmers attach secondary names created after the second most distinct trait. The mid hill farmers distinguish the taro variety ‘Karkalo’ by a pre-fix based on plant pigmentation e.g. colour of petiole or plant sap. As described in Chapter 9, *Tarai* farmers cultivate very similar taro varieties but distinguish them with different names created based on plant pigmentation. In other instances, farmers distinguish diversity by nicknames created after traits that resemble traits in other species. ‘Hattipow’ or ‘Bhaishi khutte’ are named because their corms look like elephant or buffalo footprints, respectively. As shown in Chapter 9, expressions of individual traits varied when taro varieties were reciprocally grown with different cultivation practices e.g. flat or deep furrow. The shape and size of corms and cormels were modified. Thus, farmers distinguish diversity names based on distinct trait(s) observed locally.

11.4.2 Farmers distinguish rice diversity with names

As with taro, rice diversity is distinguished by names created on the basis of a) the cultivar specific trait(s); b) the area where a particular cultivar traditionally came from; c) the cultivar specific socio-cultural values; and d) the cultivars that grow under a specific growing season. In most instances, improved or introduced varieties are recognised with the same name especially when names are not created after distinct variety traits. Cultivars are also distinguished by nicknames or secondary names. The rationale behind farmers' naming cultivars across study areas where the people speak different dialects was found to be similar (Chapter 7). Further discussions are needed to elaborate whether farmers cultivating diversity under stressed and favourable environments, refer to similar traits while naming varieties.

Farmers consider sensitivity to day length, low temperature, and tolerance to drought, water logging, and low soil fertility as distinct adaptive traits, and are referred to in the naming of varieties. As discussed in Chapter 7, farmers were consistent in names, especially of those varieties cultivated under favourable environments. Conversely, farmers cultivating diversity under stressed environments, especially in high hills were inconsistent in naming varieties. Unlike in the mid hills, the high hill farmers were inconsistent in naming rice varieties (Bajarcharya, 2004). There could be several reasons for such inconsistencies. The high hill farmers might have observed variation within a variety grown under different moisture regimes. The reciprocal experiment conducted across moisture regimes (Chapter 10) revealed that the performance of different landrace populations was greatly influenced by ecosystem factors. Therefore, distinct traits for stressed and favourable environments could be different. Farmers apply naming systems according to the altered expression of some varieties. Accordingly, farmers give different names based on distinct trait(s) if variety expressions were different than when grown in the traditional habitat. As reviewed in Chapter 5, some landraces only express certain traits under specific environments and their expression differs when grown away from their traditional habitats. Such changes of some traits might affect farmers' naming systems. These names distinguish diversity although farmers of the other locations recognise the same variety with different names, especially when created after their distinct traits observed at that locality (Chapter 4). Research evidence shows that rice quality traits are affected by environment or management factors. Some landraces are famous for their grain qualities only when grown under specific environments or niches (Chapter 8). As evident in Chapters 9 and 10, performance of individual traits is affected by the environment and management factors. Thus, names approximate diversity better when created after genetically inherited traits which are least affected by environment and/or management factors. Further investigations are required to examine the influence of environment or management factors in farmers' naming systems both for taro and rice.

11.5 Adaptation of taro diversity

Chapters 3, 5 and 9 described the distribution of taro diversity and its production environments. The main results from independent research conducted across different altitudes and management practices, are discussed.

11.5.1 Adaptation of taro diversity to different altitudes

Unlike the tradition of growing cultivars only at specific-locations, the present research shows that taro cultivars, regardless of origin, grow widely across altitudinal gradients. The degree of adaptedness, however, differs by botanical groups. Cultivars that produce corms (*C. esculenta* var. esculenta) perform better in warmer climatic conditions while those producing cormels (*C. esculenta* var. antiquorum) perform better in temperate climates. Unlike high hill and plain *Tarai* the mid hill farmers grow different botanical varieties under variable ecosystems. This research reveals more potential variety options for *Tarai* and high hill farmers who presently use only a few varieties. The research concludes that variety performance and consumers' preferences greatly contribute to taro conservation on-farm. Along with varietal performance, farmers' preference also plays an important role when adopting varieties. The variety from the *Tarai* plain that out-yielded other varieties under mid hill conditions was generally preferred by farmers at both locations (Chapter 9). The direct introduction of such widely preferred varieties to a new locality could have manifold implications for biodiversity conservation and sustainable agriculture. Along with wider cultivation of some of the preferred varieties, the existing diversity could decrease especially when i) the local landraces do not produce a competitive yield ii) resemble the same traits as the introduced varieties and iii) local landraces have limited use value instead of multiple uses. In another situation, diversity may be increased when individual varieties are grown for more different purposes. Introduction of more competitive taro varieties across the geographic region will increase diversity and thereby enhance sustainable agriculture. Apart from the promotion of germplasm exchange there is a need for the continuous monitoring of this diversity that ensures conservation before some varieties vanish from the system. Such varieties need conservation attention because farmers maintain them until they continuously provide comparative benefits.

11.5.2 Adaptation of taro diversity to different management practices

Local farmers gave several reasons for the adoption of location-specific practices. Farmers' perceptions regarding the effects of management practices were found to be different between study areas. The mid hill farmers opined that flat planted taro grown with organic manures and mulch is tastier compared to those produced with chemical fertilizers. Similarly, growing taros in dibbles with mulch not only suppresses weed growth, but also protects the crop from early season drought. The *Tarai* farmers, however, never thought of such effects though they have been growing taro since their forefathers' generations. Instead they stress that marketable taros needs to be grown in deep furrows with chemical fertilizers and irrigation. Planting in deep furrows facilitates the production of long and uniform corms. Unlike hill farmers, *Tarai* and urban consumers select specific shapes and sizes of taro corms. As presented in Chapter 9 planting methods affect the shape and size of corms and cormels. Along with yield performance and taste, the consumers' preference of shape and size affects market demand. Other studies have also shown that different practices affect product qualities. The plots with mulch and organic fertilizers produce significantly higher yields than plots with herbicide weed control and inorganic fertilizers (Miyasaka, Hollyer and Kodani, 2001). In another study, inorganic fertilizers resulted in no marked increase in marketable corms, but the quantity of non-marketable corm was significantly greater. Biomass was greater using inorganic fertilizers, but the efficiency of use of applied nitrogen was low, and fertilizer recovery was only 10%. In most instances, nitrogen fertilizer failed to increase the yield of taro (Hartemink *et al*., 2000). The percentage dry matter was enhanced with organic fertilizers and mulch over taros produced with inorganic fertilizers. Despite increased levels, foliar concentrations of nitrogen and calcium were lower in taro grown in mulch treated plots compared to non-mulched plots (Miyasaka *et al*., 2001). This finding supports farmers' claim that taro produced organically are tastier than those produced with inorganic fertilizers. This could be due to growth dilution effects as described by Jarrell and Beverley (1986). However, farmer's perceptions were inconsistent. The persistence of location-specific perceptions could be related to difference on consumers' preferences for taste, shape or size of the taro produce. Broad leaved plants, including taro are more sensitive to nutrient deficiencies than grass-type cereal crops, which may explain why taro does better with organic fertilizers and rice with the N and P fertilizers. The present taro diversity is likely to be continued as long as traditional ecosystems and consumer preferences persist and farmers secure various forms of benefits from taro cultivation. In conclusion it is the adaptive and market traits that enhance diversity no matter which environments farmers have been growing these cultivars.

11.6 Wide and narrow adaptation of rice diversity

The improved variety consistently produced good yields in all ecosystems especially on the high hill site. In the high hills, the landrace populations coming from higher elevation performed better than those from lower elevations, showing a certain degree of localized adaptation. In the mid hills, landraces coming from more favorable (irrigated) environments outperformed the improved varieties across moisture regimes. Generally, the study reveals that some landraces grown at their traditional habitats still grow well away from their habitats where cultivation practices are similar. On the *Tarai* plain, traditional varieties from rain fed environments out-yielded all tested cultivars, especially at their traditional habitats. The improved and introduced varieties consistently produced high yields, regardless of ecosystem.

This research shows the possibility of expansion of some rice cultivars to alternative environments where farmers' options have been limited. This research identified some crucial traits that prevent direct introduction of landraces to other rice growing environments. Unlike improved varieties, all rice landraces were found to be photoperiod sensitive and therefore can only be grown in specific seasons. Despite their yield potential, direct introduction of landraces away from their traditional habitats is restricted, especially when the crop planting time and growing season markedly differ from traditional practices.

The persistence of rich rice diversity under irrigated ecosystems was associated with the maintenance of landraces for quality traits not found on modern varieties. Unlike coarser grained varieties which grow better under stressed environments, the quality rice varieties are grown in more favourable environments. There was a disagreement between experimental results and the traditional practice of keeping landraces in their traditional habitats. As evident from Chapter 10, some landraces performed well even away from their traditional habitats. Similarly, some improved varieties, though developed and recommended for more favourable environments, grew well under stressed environments. Although the most improved varieties were more affected by ecosystem factors than landraces the evidence shows that the present practices have limited the use of crop diversity. Allard (1997) stated that modern cultivars are much better adapted and much more productive in agricultural environments than their wild ancestors. In this research where the performance of landraces and improved varieties when compared showed that some landraces perform better than the improved varieties especially under stressed environment. Along with wider adoption of modern varieties, most landraces, especially in favourable environments, are being grown on a reduced scale. In response to increasing food demand, farmers have been continuously changing rice environments, which may lead to a situation where traditionally grown landraces are increasingly marginalised by introduced varieties.

The research conducted at high altitude area revealed that an improved variety (Zhingling 78) out-yielded all landraces under favorable as well as stressed environments. In the mid hills, the improved variety performed relatively poorly across all ecosystems. Although the improved variety was developed using a landrace as one of the parents it is important to record its poorer performance in stressed environments and a superior performance of another improved variety which does not contain landraces. The following points can be drawn:

i) the wide ecological adaptation of improved varieties developed for target environments found across the wide geographic area

ii) the localized adaptation of landraces traditionally grown under specific environment or niches, and

iii) the wide adaptation of some landraces traditionally grown under particular rice environment

This research clearly showed that adaptive and market traits enhance diversity on-farm, no matter in which ecosystems or niches these genotypes are currently grown in.

Only recently, scientists have been using advanced techniques to identify genes governing particular traits (Brown, 2000; Demissie and Bjørnstad, 1996; Bjørnstad *et al.*, 1997). Such techniques have enabled researchers to successfully incorporate desirable traits when developing new varieties. Such research needs to be used in such a way that plant breeders not only engage in developing new varieties, but also in managing diversity for present and future use. Promotion of more competitive landraces toward alternative growing environments enhances their utilization. Such landraces support livelihoods and contribute to conservation on-farm. However, such favoured ones might displace some existing landraces. To ensure their preservation through use certain mechanisms are needed that continuously monitor diversity on-farm. At the same time the landraces that have certain distinct traits, by which they have survived, needs to be used in developing more adaptable improved varieties.

11.7 Managed diversity enhances sustainable livelihoods

Although the greatest contribution to livelihoods comes from agriculture, other non-agriculture sectors are important to farmers, especially those identified as medium or poorer households (Chapter 2)**.** Unlike diversified livelihood strategies adapted by subsistence farmers, more specialized strategies are common among households with improved access to inputs, markets and technical services such as in the *Tarai* plain. The present research elaborates important contribution of diversity and knowledge to sustainable livelihoods. Farmers' maintenance of diversity is dependent on potential economic and local use values attached to the individual varieties. Nepali farmers have been conserving rice landraces mainly for different food uses and socio-cultural values, which affect on-farm conservation strategies (Chapters 6 and 7). Rana (2004) documented that Nepali farmers maintain crop diversity for different food tradition, culture and adaptive values.

It is important to understand the degree to which farmers value their landraces. Farmers might value a variety for a single or a combination of a number of traits. A study conducted to determine farmers' willingness to pay for the conservation of rice landraces on-farm reveals that farmers' willingness to pay for conservation is related to the food/taste quality attached to the particular landrace (Poudel *et al.*, 2005). Other research was conducted to determine the cost of maintenance of landraces and improved varieties of rice on the *Tarai* plain. The total cost for the maintenance of landraces was found to be higher than for improved varieties, which was due to low grain yield from the landraces (Gauchan, 1999). The research, however, failed to distinguish conservation costs involved for high and low quality landraces. As illustrated above, landraces are grown when i) they are competitive compared to other options farmers have, ii) farmers have no alternative other than landraces for their specific adaptive traits or uses they require and, iii) farmers need special varieties and have no other varieties with similar traits. Local needs and preferences, along with government policies and farmers' own initiatives and farming systems are changing over time. In response to such changes, crop diversity is shaped and re-shaped to meet ecosystem requirements and site-specific needs. Sustainable on-farm conservation is possible only when farming communities and the nation perceive benefits in terms of genetic, economic, social, and ecological aspects (Raymond and Fowler, 2001).

The livelihood strategies are subject to change with improved access to agricultural inputs and high-yielding varieties, as well as to improved markets and technical services. Since diversity and livelihoods are directly related, especially under subsistence farming, on-farm conservation becomes successful only when cultivar diversity meets local needs related to adaptation, food, and local culture. Some important strategies can be employed by which crop diversity can be exploited further for sustainable livelihoods. The low yielding landraces which are currently known for their special traits could be grown at reduced scales on-farm, but at the same time could be used for breeding new varieties through decentralised and/or conventional breeding. Any research and development initiatives that improve productivity and economic benefits from traditional varieties would support livelihoods. To make landraces more competitive, demand for their derived products can be improved through breeding for traits that have special food values. Similarly, demand for landraces can be expanded directly by market promotion. By means of adding value, demand for low yielding, but precious landraces can be expanded and/or created. As presented in chapter 6, demand for taro-derived products can be enhanced through new recipe development or improved processing. Farmers' choice of rice cultivars for aromatic and fine grain as well as stickiness for traditional dishes could be targeted at niche markets. Such initiatives may affect farmers' maintenance of diversity on-farm.

When some varieties become favored or preferred, they might be grown more widely by many farmers, which at the same time might displace other varieties that are less competitive with respect to adaptive or economic values. Farmers continuously work and rework with crop diversity, environments and knowledge in response to ever changing local food and cultural needs. To meet the ever increasing food demand, farmers may expand areas under a few improved crop varieties especially in more favorable environments. Farmers' management strategies are thus changed along with the creation or infusion of new knowledge. The creation and recreation of knowledge about crop diversity affects livelihood options and on-farm conservation strategies.

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