Dynamics of livestock development in Gujarat, India: Experiences of an Indian NGO

B.R. Patil

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Abstract

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Smallholder mixed crop livestock systems continue to be a dominant agricultural production system in many developing countries, including India. Dairy farming is part and parcel of many such systems, and it is often seen as an important livelihood option to increase household income and to therefore contribute to poverty alleviation in rural areas. As a result, substantial efforts in agricultural R&D have been directed towards design of new technologies for smallholder dairy farming. Variable success in technology transfer has clearly shown that adoption is context-specific, related to the physical and socio-economic environment, access of farmers to resources, access to information and personal attitudes. A series of concepts and methods were developed to incorporate these considerations, and to replace narrow technology-driven approaches by broader ones such as Farming Systems Research (FSR).

This thesis describes and analyses experiences of BAIF, an Indian NGO, with the use of FSR methodology in livestock development programmes in Gujarat, India. The objectives were to identify criteria and methodologies for selection of appropriate livestock technologies for farm level, and to identify differences in the methods of selection of appropriate technology. Section 1 describes the variation in livestock production systems in India in general and in Gujarat-state. Livestock comprises defined and undefined breeds of cattle and buffalo. Total livestock population increased annually by over 1% in the last four decades, with buffalo and goat populations increasing faster than cattle. This section also gives background to the BAIF organization and to FSR methodologies. Section 2 more specifically describes the Gujarat research area with agro-ecological zone-wise information on animal breeds, herd composition, feed resources, crops, and trends in seasonal availability of feed as derived from transects, Participatory Rural Appraisals, and mapping. Constraint analysis and modelling indicated limited genetic potential of the local breeds and shortage of feed resources, both quantitatively and qualitatively, as major constraints for livestock development. Crossbreeding for breed improvement and use of (improved) local feed resources were identified as suitable technologies to alleviate these constraints.

Ex-post performance monitoring of some BAIF crossbreeding programmes show that crossbred cattle fitted well in the smallholder mixed farming systems of both tribal and non-tribal farmers in all three selected agro-ecological zones (Section 3). Milk production of crossbreds was substantially higher, as was livestock gross margin and household income. Although quality of the roughages is a major limiting factor, farmers owning crossbreds tried to adjust to the needs of the cows by feeding concentrates. There was no difference in workload and labour division between households with and without crossbreds. Crossbreeding thus proved a techno-economically and socially viable livelihood option for both mixed and landless farming systems in Gujarat.

Various modelling approaches were used in Section 4 to explore, *ex ante,* the suitability of feeding technologies such as urea supplementation, use of local and commercial concentrates, urea-treated straw with concentrates, and leuceana tree leaves for crop-livestock systems in Gujarat, India. Major conclusions were that (i) concentrate feeding is beneficial to farmers with market access and crossbred cows, (ii) crossbreeding interventions are more remunerative for landless and tribal farmers than for non-tribal farmers; feeding interventions are more effective for crossbreds than for local cows, (iii) maximum farm income is achieved at medium milk yields per animal; higher milk yields require use of better feeds, which renders the straws of the grains useless for feeding; at farm level, the (economically) optimum cropping pattern would then shift from grain crops to cotton. This section continues with a narrative on BAIF's experiences with field testing of technologies at animal, at herd, at farm and watershed level, including a shift to crop research when dictated by local needs. Over a period of roughly 30 years, three phases in on-field testing can be distinguished, i.e., starting with a period of predominantly top-down approaches, moving to a phase with emphasis on participatory identification and testing of technologies, and then into a phase with work at community and watershed level. A few cases are discussed for each phase, illustrating the processes, methods and types of technologies involved, and drawing lessons on field experimentation for livestock and rural development in general. The studies brought out, among others, that adoption of technologies is facilitated when these use local (feed) resources, that are readily available, requires only small changes in farm practices, are relatively simple to implement, and yield tangible results in the short term.

Section 5 analyses the dynamics in methods and approaches of BAIF's work on livestock development, as it grew from Gandhian roots into a large development organization. It emphasises the dynamics in approaches between top-down, objectivist and reductionist approaches on one hand and bottom-up, constructivist, holistic and self-organized approaches on the other hand. These experiences are set against similar developments on the (inter)national scene and in industrialized countries, along with factors that influence the changes, suggesting that agricultural R&D behaves as a complex adaptive system with its own dynamics and associated paradigm shifts. It also discusses a number of cross-cutting issues such as the notion of real *versus* perceived problems, hierarchy and grid, phases in development and aspects of holism *versus* reductionism, also reflected in notions of goal and process orientation. Concluding, the thesis considers development as a continuous process, of which the goals change over time-and-space. This reflects a paradigm issue, and if development is indeed a dynamic process it implies that choice of methodology and technology) should go along with changes occurring in that process. Some guidelines regarding the usefulness of approaches and technologies are given. But agricultural R&D is ultimately considered to be a complex adaptive system, also in Gujarat, and development organizations such as BAIF have to, therefore, show dynamic behaviour.

Keywords: Agricultural R&D, field experimentation, crossbreeding, dairy, feeding technologies, mixed farming, farming systems research, modelling.

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B.R. Patil

Contents

CHAPTER 1

Dynamics of livestock development in Gujarat, India

Introduction

Smallholder crop livestock mixed farming will continue to be the dominant livestock production system in developing countries (Devendra, 2002; Udo, 2002). Mixed farming systems produce 92% of the global milk supply. About 50% of the total milk and meat produced in these systems comes from developing countries (Thomas *et al*., 2001; FAO, 2005; Owen *et al*., 2005).

In mixed farming systems, livestock are kept for various reasons such as food security, income, employment, manure, draught, fuel, savings, socio-cultural objectives and as an insurance for urgent cash needs. Different types of livestock perform different functions for production and/or as capital asset. The capital asset function of livestock is important in areas lacking formal insurance and credit mechanisms. Keeping livestock is an insurance against events requiring (unexpected) appreciable cash outlays, such as a wedding, a funeral, hospitalization of a household member, renovation of the house, education expenses for children, and other social obligations for religious functions or symbolic exchange in hospitality (Slingerland *et al*., 1998; Udo, 2002; Moll, 2005).

Dairy farming is often advocated as an important livelihood option to increase the income of mixed farms and, therefore, to contribute to poverty alleviation in rural areas (Apte, 1989; Dolberg, 2001; Thornton *et al*., 2002; Morrenhof *et al*., 2004). India is prominent among developing countries in promoting dairying. In India, milk and milk products have always been substantial components of the human diet and many local breeds are relatively good milk producers, although also here crossbreeding for dairying is widely used. India is now the world's leading milk producing country with a total annual output of almost 92 million tonnes, of which 34.5 million tonnes of cow milk (FAOSTAT, 2006), that is more than 13% of the total world milk production. The annual growth rate in milk production is 5–6%.

Within mixed farming systems a wide variation exists. They can range from mixing at farm level to regional level. They are integrated with intensive exchange of resources such as crop residues and dung between crops and livestock or take more diversified forms with little interconnectedness (Schiere *et al*., 2002; Van Keulen and Schiere, 2004; Schiere *et al*., 2006). The actual shape of any farming system is influenced by physical, ecological, economic and cultural factors, e.g., by agro-ecological conditions, natural resources and their qualities, access to resources and services, social and political vulnerability, indebtedness and market opportunities (Bagachee, 1990; Ghosh, 1991; Dixon *et al.*, 2001). Within a given agro-climatic region, opportunities for a farmer in peri-urban areas might differ from those in rural areas. In addition, differences arise from diversity in social fabric, such as religion, ethnic group and caste.

In the course of history different systems have developed, moving from extensive cultivation and livestock keeping towards more intensive systems (Gahlot *et al.*, 1993; Nair and Dhas, 1989). Pastoralist herders of ancient days, invaders from the north around 1000 A.D. and migrants from arid regions of Afghanistan and the Indo-Pakistan region of South Asia have contributed to evolution of breeds and livestock husbandry (Hasnain and Karam Shah, 1985; Randhava, 1986). Growing population pressure and the associated increasing demands for food led to intensification and an associated change from grazing to mixed farming systems (Gass and Sumberg, 1993; De Haan *et al.*, 1997). These developments were based on wisdom from trial and error by livestock keepers, i.e., accumulated indigenous technical knowledge, autonomous from formal research. Such processes took place not only in India, but also elsewhere in the world, and, in general, more rapidly in densely populated regions (Ruthenberg, 1980; Hayami and Ruttan, 1985; Randhava, 1986; Patel *et al.*, 1993; Van der Ploeg and Long, 1994; Schiere *et al.*, 2002). These developments always combine external and internal factors, such as the environment, the needs of a growing population, changing access to information and/or to technological inputs, local resources, skills and indigenous knowledge (De Haan *et al.*, 1997). For example, the introduction of green revolution technologies through high-yielding varieties and livestock development through crossbreeding, since the 1960s in India, has led to intensification of crop and livestock production based on the use of external inputs (George *et al.*, 1989; Nair and Dhas, 1989).

In Schultz' opinion (1964, quoted in Hayami and Ruttan, 1985), peasants in traditional agriculture are rational, efficient resource allocators and they remain poor because of their limited technical and economic opportunities. Similarly, the Indian leader Mahatma Gandhi used to say that farmers are poor because their resources such as land, livestock, water and vegetation are limited and of poor quality. This led in his view to a vicious circle of underemployment and social problems of poverty and migration. He maintained that a change to sustainable development should be achieved by converting the resources into more productive assets through technological innovation, using local knowledge and skills. Gandhi referred to the (integrated) development of the *whole* village, but many subsequent research and extension activities for agricultural development in the green revolution era of the 1960s and

1970s focused on *components* of the agricultural system. Scientists and policy makers tended to assume that improvement in one place would be replicable in other places (Röling, 1989; Conway and Barbier, 1990; Collinson, 2000). Most of the crop research of the past half century has focused on yield increases of single crops, or on disease and pest control or irrigation of a particular area, forestation and promotion of horticulture. In philosophical terms, that work was based on the use of reductionist and objectivist paradigms (Röling, 1996). It focused on parts (reductionism), while assuming that an intervention in one part of a system would not have unexpected effects elsewhere in the system. In other words, it ignored interconnectedness, i.e., relations and exchange among parts of the systems. It assumed that proper scientific research yields unambiguous answers (objectivism) to questions encountered in the field, where farmers' conditions and perceptions change from place to place and in the course of time (Shaner *et al.*, 1982; Gibbon, 1994; Röling, 1996; Ison and Russell, 1999; Collinson, 2000; Schiere *et al.,* 2004a). Research in animal production has been no exception to the approaches in crop research. For example, research on feeding of special protein sources and fodder varieties and on new straw feeding methods, as well as on genetic improvement of animals and health care tended to assume that higher yields are always useful, regardless of the local socio-economic and biophysical conditions (Chambers, 1997; Schiere *et al.*, 2000; Udo, 2002).

This study illustrates the experiences of BAIF (an Indian NGO), working for up-liftment of rural poor in Gujarat, India, through livestock development as a tool to increase the family income. Gujarat, a forefront state in dairy production and cooperatives, is dominated by smallholder crop livestock mixed farming. This study narrates the use of methodologies and approaches in selecting and applying suitable technologies for livestock development, under diverse situations of socio-cultural and agro-climatic conditions.

The Indian context

Geography and topography

India comprises a vast peninsula in the south of the Asian continent, shaped like an irregular square with a territory of 3.3 million km^2. The country is landlocked in the north by the ranges of the Himalayan mountains and waterlocked in the south by the Indian ocean. On the west is the Arabian Sea, and Pakistan lies in the Northwest and in the east one finds the Bay of Bengal and Myanmar (Figure 1).

The country lies between 8° 4′ and 37° 6′ Northern latitude, and between 68° 7′ and 97° 25′ Eastern longitude. The Vindya Mountains, running west to east separate the north and south of the country. The North Indian plains, comprising the Indus (Sindhu) basin, the Ganges-Brahmaputra basin and those of its tributaries, are characterized by fertile alluvial clay and loam soils. In the South lies the plateau of Peninsular India, comprising the Malwa and Deccan plateaus. The Malwa plateau is surrounded by the Aravali hills in the northwest. The valley of the Narmada River forms the southern boundary. The Malwa plateau is characterized by alluvial deep black, medium-shallow black, mixed red and yellow soils. The Deccan plateau extends from the Satapura hills to Kanyakumary, the southernmost point of India. Towards the West of the plateau one finds the western ‘Ghats’, comprising the Sahyadri, Nilgiri, Annamalai and Cordemum hills in the west, and the eastern ‘Ghats’ towards the South. Soils of the western ‘Ghats’ are characterized by laterite and lateritic, coastal alluvial, saline-alkali, mixed red to black and coarse soils on the hill slopes. The eastern ‘Ghats’ are characterized by red loamy, red sandy, alluvial, laterite and lateritic soils, and coastal sandy soils.

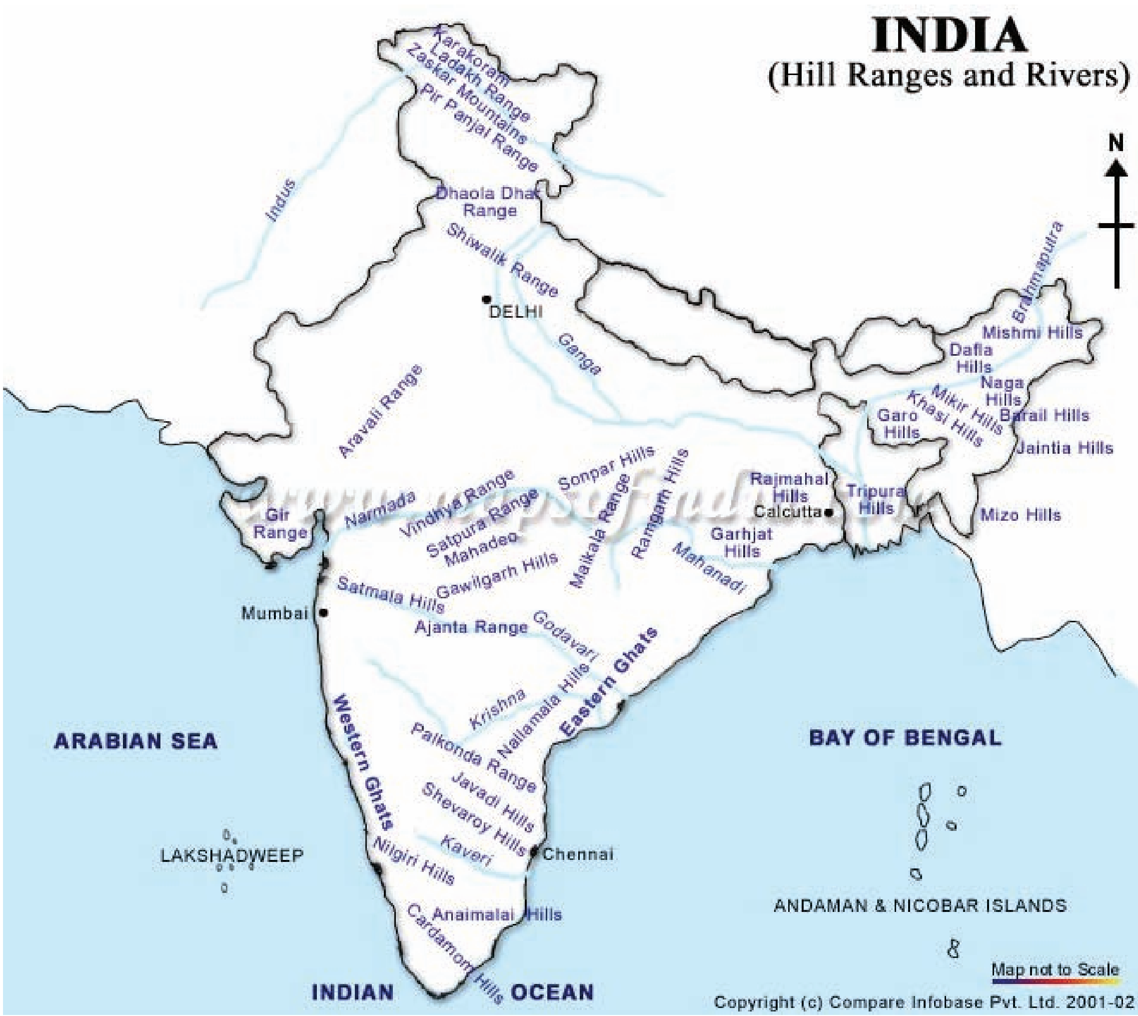

Figure 1. Map of India with hills and ranges.

Population and demography

India is home to a large and diverse population of over one billion, with a 65% literacy rate (Census 2001). People speak different languages and follow different religions and customs (Anonymous, 2000b). Over 3,000 diverse communities live together, of which 8% are classified as tribal, socio-economically less favoured ethnic communities with a low literacy rate (Masawi, 1988). Some 20 major religious movements exist, with Hinduism, Jain, Sikh, Buddhism, Christianity and Islam as the most important ones. India has Sanskrit as an ancient language, but is home to 325 languages (26 official ones) and 25 scripts. The majority of the population lives in rural areas (70%) and derives its livelihood from agriculture, with mixed crop-livestock farming as the major system (Apte, 1989; Singh *et al.*, 1995).

Agroclimatology

Rainfed farming is predominant in the country, with only 31% irrigated area. Major crops are paddy, wheat, sorghum, cotton, millets, sugarcane, groundnut and other pulses, while mango, banana, apples and grapes are the major fruits in the country. Tropical (arid, humid, sub-humid) and sub-tropical climates are spread over different regions in the country. Rainfall pattern is influenced by the southwest and northeast monsoons. Annual rainfall widely varies, from 50 mm in desert areas to 3500 mm in the northeast. Mean daily temperatures vary from lower than 0 °C in winter to as high as 48 °C in summer. The northern high-altitude ranges of the Himalaya experience heavy snowfall during winter.

For the purpose of national agricultural planning and research, the Indian Council of Agricultural Research (ICAR) has divided the country into 15 major agroclimatic regions (Figure 2), which are further subdivided into 120 micro agroclimatic regions, based on soils, climate and cropping patterns (Ghosh, 1991). The study area, Gujarat State, is part of the Gujarat Plain and Hills Region, which is subdivided into 8 micro agroclimatic zones. Gujarat State, with a total area of about 19.6 Mha, is largely agrarian in character, with 50% of its area under cultivation. Based on its physical features, Gujarat is divided in three main regions (i) mainland plains extending from north to south, (ii) hilly peninsular region of Saurashtra, (iii) hilly tract in the northeast and east. The region in the extreme north has an arid climate, the extreme south a sub-humid climate and the remainder of the state is semi-arid. Average annual rainfall varies from 300 to 2,000 mm (Ghosh, 1991). Annual average minimum temperature is 15 °C and the maximum is 42 °C.

Livestock in India

Livestock keeping has been for very long, an integral part of Indian farming

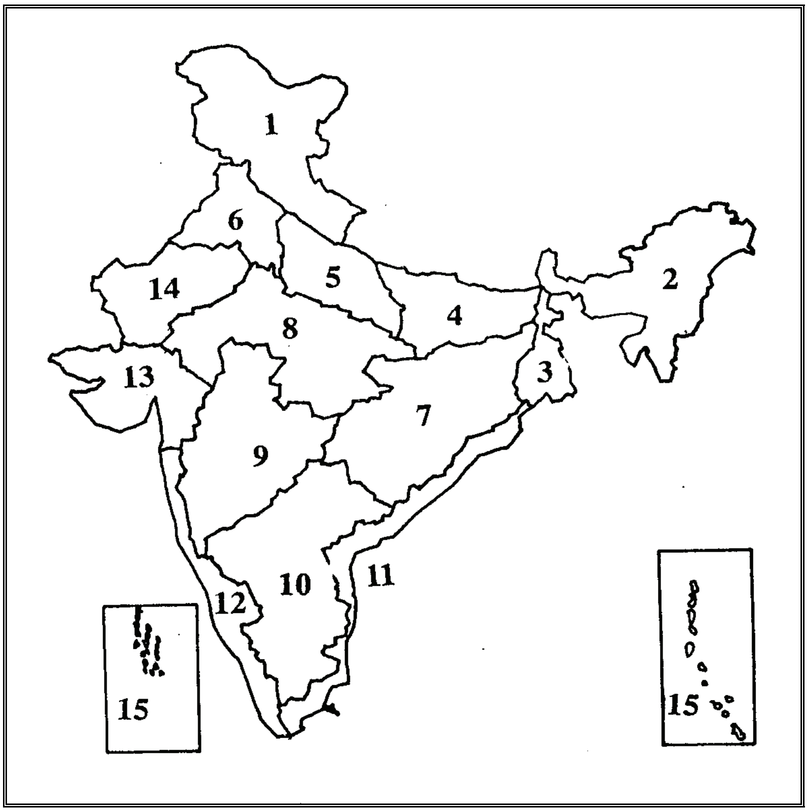

Figure 2. Agro-climatic regions of India according to NARP, ICAR. 1. Western Himalayan Region, 2. Eastern Himalayan Region, 3. Lower Gangetic Plain Region, 4. Middle Gangetic Plain Region, 5. Upper Gangetic Plain Region, 6. Trans-Gangetic Plain Region, 7. Eastern Plateau & Hills Region, 8. Central Plateau & Hills Region, 9. Western Plateau & Hills Region, 10. Southern Plateau & Hills Region, 11. East Coast Plains & Hills Region, 12. West Coast Plains & Hills Region, 13. Gujarat Plains & Hills Region, 14. Western Dry Region, 15. Island Region.

(Randhava, 1986). Evidence of livestock keeping is found in the oldest Indian scriptures, such as the Atharvaveda, Ayurveda and Rigveda and in archaeological remains of the Harappan era in the Indus civilization (about 2000 B.C.), including a coin bearing the figure of a bull and terracotta bullock carts (Narang, 2002).

Particularly cows have been regarded in India as sacred since ancient times, among others for providing vital services from often very meagre feed resources (Harris, 1967). Cows, almost as a metaphor for all other livestock, rarely serve one distinct single purpose. As a matter of paradigm, we will see in this thesis that cows fulfil a range of functions, of which the relative contribution to total ‘usefulness’ can vary considerably over time and space. For example, many references to cows and cow milk in ancient scriptures, such as the Vedas, Mahabharata and Charak shastra (ancient book in medical science written by the eminent physician Charak in the Vedic period, around 1000 B.C.) indicate that cow milk and milk products were being used in ancient India, for nutrition as well as for curative and prophylactic medicinal purposes (cf. the ninth mantra of the 73rd Sukta in the 10th Chapter of the Rigveda (Rigveda 10-73-9)). Charak describes cow milk as tasteful, sweet, fine flavoured, dense, containing light fat, easily digestible, and not easily spoilable (Figure 3). It gives tranquillity and cheerfulness and helps build up vitality. This curative and prophylactic effect is partly because of the medicinal herbs cows eat (Narang, 2002). At least partly because of these qualities, the cow has been treated as a sacred animal: '*cow mother*' or '*kamdhenu*'. Reference is made to the cow as provider of 'Amrita', the milk, an elixir, a sip of which can make one free from all sufferings and diseases, and immortal. Irrespective of whether or not milk was such an elixir, the text is an indication of its symbolic role in life (Mahabharata Anu. 65-46). Last but not least, in the great Hindu epic Mahabharata (composed around 500 B.C.), it is Lord Krishna, the saviour and herdsman of the cows, who reminds us of past glory, i.e., of having '*dugdha dharas*', the stream of milk, in the land of '*kamdhenu*s'. In other words, the cow meant much more (metaphor - *kamdhenu*) than only milk and human nutrition. It implies freedom from suffering, acquiring vitality, with tranquillity and prosperity. This carries a symbolic notion of a holistic approach to the well-being of man and society. Not only physical aspects of the body are important, but other aspects such as emotions, feeling, mind, soul and spirituality. This view reflects at the human level, attention to a more holistic approach, similar to the biophysical and socio-cultural aspects in integrated rural development.

Present livestock population

Presently, India has the largest livestock population in the world, but it does not enjoy its past glory. It lacks '*dugdha dhara*', the milk stream and the '*kamdhenu*', the high-yielding cows. Per capita milk availability is below the dietary requirements and consumption is much lower than in developed countries (Anonymous, 1997). The

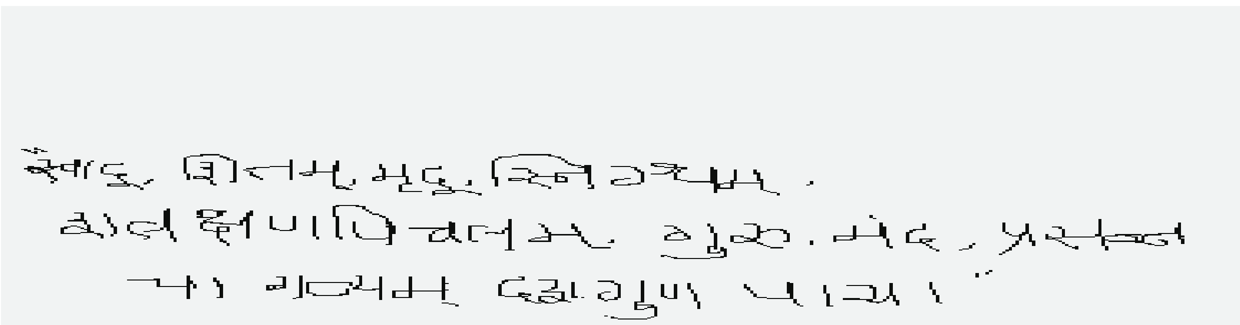

Figure 3. Mantra in Sanskrit from Rigveda.

bovine population in India of 283 million (2005) represents 18% of the world population (1,529 million), with 14% and 53% of the world cattle and buffalo population, respectively (Table 1). India derives 24% of its Gross Domestic Product (GDP) from agriculture (Anonymous, 2003a), with the livestock share estimated at 26% of the total agricultural sector. Small farmers are the major contributors to livestock production (Kiran Singh *et al*., 1997; Devendra, 2000). They share a total of 483 million head of livestock, of which 43% are cattle and 18% buffaloes. India has about 28 well-defined breeds of cattle *(Bos indicus)* and about 8 breeds of river buffalo (Anonymous, 1997; Kiran Singh *et al*., 1997). Major dairy breeds are Sahiwal, Red Sindhi and Gir, with production levels of 1,000–2,000 kg per lactation, and there is a small population of 7 million dairy-type crossbred cows. Dual purpose breeds for milk and draught are Tharparkar, Hariana, Kankarej, Rathi, Ongole, Deoni and Gaolo, with milk production levels of 600–1,500 kg per lactation. The major draught breeds are Hallikar, Khillar and Dangi, producing less than 500 kg of milk per lactation. The eight defined milk buffalo breeds are Murrha, Surati, Mahasani, Jafarbadi, Nagpuri, Niliravi, Pandharpuri and Bhadawari with production levels of 1,200–2,000 kg milk

Table 1. Livestock population (millions) in India 1956-2005.

CATEGORY	1956	1961	1972	1982	1992	1997	2005[1]
Cattle	158	175	178	192	204	198	185
Buffalo	44	51	57	69	83	89	98
Total Bovines	203	226	235	262	288	288	283
Sheep	39	40	40	48	50	57	62.5
Goats	55	60	67	95	115	122	120
Horses and Ponies	1.50	1.30	0.90	0.90	0.82	0.82	0.80
Camels	0.80	0.90	1.10	1.08	1.03	0.91	0.64
Pigs	4.90	5.20	6.90	10.07	12.79	13.29	14.3
Mules	0.04	0.05	0.08	0.13	0.20	0.22	0.30
Donkeys	1.10	1.10	1.00	1.00	0.97	0.88	0.75
Yaks	N.C.	0.02	0.04	0.13	0.06	0.05	n.a.
Total Livestock	306	335.40	353.40	419.59	470.14	485.38	482.3
Poultry	94.80	114.20	138.50	207.74	307.07	347.61	430

Note: The census was not conducted in Bihar, Karnataka, Kerala, Punjab and Sikkim in 1992 and in Bihar, Himachal Pradesh, West Bengal and Dadra and Nagar Haveli in 1997, (which is the latest available), for which projections were used (Anonymous, 2000c).
N.C. - not collected.
[1] FAOSTAT, 2006.

per lactation (Anonymous, 1997; Kiran Singh *et al*., 1997; Cunningham and Syrstad, 1987).

Livestock population, some changes

The annual growth rate of the overall bovine population from 1956 to 2005 was about 1.04% (Table 1), with appreciable differences among species and regions. The overall annual growth rate was 0.63% for cattle, 2.5% for buffalo and 3.05% for goats. While the buffalo population increased by 10.1% in last decade (1997–2005), the cattle population has declined by –0.65% in the same period. The total cattle population remained high, among others because of prevailing religious sentiments, which dissuade the people from slaughtering cows and the dependence of the farmers on bullock power (40% of the cattle) for draught and transport. Due to increased mechanization, reduced land holdings and introduction of alternative means of transport, the population of bullocks is, however, stagnant or decreasing (George *et al.*, 1989; Kelley and Parthasarthy Rao, 1994). In particular in the eastern region, the proportion of cows in the cattle population increased (Kelley and Parthasarthy Rao, 1994), perhaps reflecting a general trend that cows are considered more useful than bullocks. Cows can produce milk, offspring, meat, manure and draught power, rather than draught power only, albeit at the expense of milk production (Jabbar, 1983).

Milk production

Milk production involves 70 million producers with one or two cattle and/or buffaloes. The major contribution is from ‘non-descript’ cattle and buffaloes (about 80 and 60% of the total cow and buffalo milk production, respectively) (Anonymous, 1997). In general, production of individual animals is very low (Table 2). Even for descript breeds, production is far below what is often called their potential. The main reason is the restricted availability and quality of feed which is often below requirements, due to pressure on land, a preference for growing cash crops and rapid industrialization. Many livestock systems are crop residue-based, which cannot sustain high levels of

Table 2. Average milk yield for different dairy animals in India (with the range) and Gujarat (kg animal^{-1} d^{-1}).

Type of animal	India	Gujarat
Cattle	1.5 (0.5–2.5)	2.4
Buffalo	3.0 (2.5–4.5)	3.4
Crossbred	6.0 (4.5–8.0)	7.9

Source: Anonymous (2000a).

Table 3. Regional distribution of milk production, human population and per capita availability (PCA) in 2003–2004 (Anonymous, 2004).

Region	Human population in million (% of total)*	Milk production in million tonnes (% of total)	PCA of milk ($g\ d^{-1}$)
Northern Region	306 (30)	41.3 (46)	370
Western and Central Region	232 (22)	19.1 (21)	227
Southern Region	223 (22)	17.7 (22)	218
Eastern Region	266 (26)	9.9 (11)	103
Total (national level)	1027 (100)	88.0 (100)	231
Gujarat State	50 (5)	5.9 (7)	330

* based on census 2001.

Northern Region: Chandigarh, Delhi, Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, Rajasthan, Uttar Pradesh. *Western and Central Region:* Dadra and Nagar Haveli, Daman and Diu, Goa, Gujarat, Madhya Pradesh, Maharashtra. *Southern Region:* Andhra Pradesh, Karnataka, Kerala, Lakshadweep, Pondicherry, Tamil Nadu. *Eastern Region:* Andaman & Nicobar, Arunachal Pradesh, Assam, Bihar, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Sikkim, Tripura, West Bengal.

production per animal. Dairy cooperatives, promoted under Operation Flood (Anonymous, 2003a) are playing an important role in procurement, processing and marketing of milk. In the year 2003, in total 170 milk unions procured 18 million kg per day (6.57 million tonnes per annum) from 11.4 million farmers (Anonymous, 2003c). Though dairy cooperatives have fostered dairy development in rural India, they procure only 20% of the total milk produced, while the remaining 80% is flowing into the informal sector through private vendors, *dudhwalas* (milkmen), and private entrepreneurs (Anonymous, 2000c).

Average per capita availability (PCA) of milk (231 $g\ d^{-1}$) is lower than the recommended level of 250 $g\ d^{-1}$ (Table 3), however, with large variations among regions, associated with regional differences in herd size and consumption habits. The Northern region has the highest milk production, while the Eastern region has the lowest, which can be explained by the larger number of dairy-type animals in the Northern region (Table 3).

Feed availability

Over the past decades, various estimates have been made of the availability and requirements of feeds and fodder for the livestock population (Kiran Singh *et al.*, 1997). Major limitations of such estimates are the uncertainty in green and dry fodder availability from pasture land and common property resources and in seasonal availability of green feeds during the monsoon, associated with the variable and erratic rainfall. Still, there is general agreement on the shortage of good quality feeds throughout India, though estimates vary widely due to the range in assumptions. For example, the Committee on Fodder and Grasses (1987) estimated an annual deficit at national level of nearly 600 million tons of green fodder and 400 million tons of dry fodder, including crop residues. On the other hand, Mudgal and Pradhan (1988) estimated deficits of 47 million tons of green fodder, 45 million tons of dry fodder and 9 million tons of concentrates, i.e., an order of magnitude lower. The policy advisory group on integrated grazing policy, Ministry of Forests, Government of India, estimated deficits of 31% in dry fodder, 23% in green fodder and 47% in concentrates for 1993, with the indication that these deficits were likely to increase, as illustrated for green fodder, which was projected at 31% during 2000. These widening gaps in feed availability force farmers to feed animals with poor quality materials, such as straw, with the associated deficiencies in both crude protein and digestible nutrients (Zemmelink, 1986; Kelley and Parthasarthy Rao, 1994). Although the information on fodder availability and feed supply needs to be judged with caution, because of the lack of accuracy, the estimates clearly indicate the wide gap between supply and demand of feeds and fodder.

Development perspectives

The Indian government and many organizations and individuals are actively pursuing the alleviation of poverty throughout the country (Baumgartner and Högger, 2004). Various programmes have been launched, such as promotion of horticulture, improved crop husbandry, dairying, goat keeping, poultry, or off-farm activities. Nevertheless, 26% of the population (still) lives in poverty on less than a dollar per day (Anonymous, 2001a). The rural population derives its livelihood mostly from mixed crop-livestock farming. Thus, dairy farming is one of the potential sectors that may contribute to increased income and poverty alleviation. To attain that objective, about four decades ago the central and state governments started programmes to increase the production of dairy cattle through crossbreeding. Parallel to these initiatives, the government motivated and supported other agencies, such as milk cooperatives and NGOs to expand their activities in the country. The BAIF Development Research Foundation is one of these NGOs that took the lead in poverty alleviation programmes and creating employment generation opportunities.

BAIF

BAIF is an Indian Non-Government Organisation (NGO), operating as a non-profit secular trust, founded by the late Dr. Manibhai Desai in 1967 based on the Gandhian philosophy. The essence of that philosophy is to work with poor, weaker sections of the community on improvements in their living conditions and attaining self-reliance with better quality of life, i.e., not relying on outside support. BAIF's mission is to improve the situation of the rural poor with emphasis on the weaker sections of society, including women, by creating gainful employment opportunities through the use of appropriate technologies, available local resources and knowledge. BAIF's development programmes are based on a deep understanding of the rural areas in western India near Pune, and especially on the experiences gained by Dr. Desai (Rangnekar, 1989). It originated from work with a dairy farm of a nature cure health centre, founded with the blessings of Mahatma Gandhi.

BAIF started by using the local traditional cultural practice of keeping at least one 'holy' cow per household, as a base to produce a productive asset (a high-yielding and high-value cow) from a non-productive local cow, that is a liability to the farmer. This objective, aiming at increasing family income, improving family nutrition and improving the quality of life, in a sense as in '*kamdhenu*', can be realized with minimum cash investment of farmers. The programme aimed at replacing low-productive Desi cows, also referred to as non-descript, by higher yielding and economically more attractive progeny. The cow thus became a tool to create gainful employment for the rural poor. BAIF introduced the use of new technologies, such as artificial insemination (AI), crossbreeding and production of improved feed resources, as well as training in feeding and management to increase the knowledge and skills of farmers with a strong backup of applied research. Training was provided, for example, in heat detection, hygiene at birth, calf care, feeding of lactating animals and other management practices. These programmes were applied across the board, based on the early experiences of BAIF near Pune. However, it was eventually realized that each farmer and farming system has its own priorities, perceptions and realities. So, as a consequence of this process, the organization slowly returned to more participatory approaches. It was a logical change to respond to the needs of farming communities outside the region where BAIF started its programmes, and where it lacked the intimate knowledge of the farming systems. In the early 1990s, BIOCON, a bilateral cooperation project between the Government of India and The Netherlands, on feeding of fibrous crop residues, in association with Wageningen University, built upon the on-going field surveys and performance monitoring of the crossbreds by introducing a formal Farming Systems Research & Extension (FSR&E) component into BAIF research programmes in the study area of Gujarat (Schiere *et al*., 2000).

Rural development: A methodological overview

Many development efforts from the 1960s till the 1990s were based on the notion that a technology shown to be successful in one situation would be acceptable and useful almost across the board. The Green Revolution consisted essentially of a package of technologies that could be applied in a rather 'scale-neutral' way and that seemed to be useful to many farmers (Benar and Baxter, 1984; Fresco, 1986). Many crossbreeding and vaccination programmes, forage improvement projects and training and visit (T&V) campaigns in animal production were either the same for everyone or they were thought to be equally useful for everyone (Röling, 1989). The T&V system was typically based on the concept that one farmer could serve as an example for many (Benar and Baxter, 1984). Eventually, however, it was realized that not all technologies were equally effective and acceptable in all situations (Jackson, 1981; Conway and Barbier, 1990; Schiere, 1993; Udo, 2002). It became clear that adoption and innovativeness were related to context, consisting of a combination of the physical and socio-economic environment, personal attitude of the farmers, their access to resources, and/or access to information and wealth (Röling, 1988; Van den Ban and Hawkins, 1988). Moreover, the perceptions of problems and priorities may vary among stakeholders and aggregation levels. For example, at national level, Gross National Product, food security and administrative boundaries are priorities, but that may not be the case at region or village level. Villagers' priorities may lie with potable drinking water, a temple, a drainage system or high prices rather than high yields. In other words, what is useful for one farmer may not be applicable to others. This was one of the reasons for the development of FSR techniques (Shaner *et al.*, 1982; Fresco, 1986; Gibbon, 1994; Collinson, 2000; Schiere *et al.*, 2000). Development agencies started to recognize the limitations of the narrow focus on parts of the system. Both, NGOs and GOs realized the impact of context on applicability of technologies. In addition, they started to realize that a small change in one part of the system could have an unexpected effect elsewhere (Conway and Barbier, 1990). As a consequence, a series of concepts and methods were designed to overcome the limitations of a narrow focus on detail, defined in broad terms as farming system research (FSR) in the international agricultural research arena (Collinson, 2000).

In essence, this development of FSR constituted a 're-discovery' of system thinking and the more holistic approaches to agricultural development (Fresco, 1986; Schiere *et al.*, 2004a). Indeed, each of the components of FSR may not have been new in itself, but in FSR they were combined into coherent sets of tools, i.e., into 'baskets' of methods for researchers to improve understanding of the farm situation and its decision-making processes (Gilbert *et al.*, 1980; Shaner *et al.*, 1982; Simmonds, 1986; Merril Sands, 1986; Mettrick, 1993; Singh *et al.*, 1995; Collinson, 2000). Generally speaking, FSR viewed the farm and the rural household in a comprehensive manner, recognizing the interdependencies between the natural and human environments. Gibbon (1994) identified two developments in FSR, i.e., a focus on participation of farmers and inclusion of farmer knowledge and experimentation. Both were used in the research process and in development of techniques for agro-ecosystems analysis, and they were incorporated in rapid rural appraisal and participatory rural appraisal techniques. This inclusion implied an important paradigm shift. It represented a move from the notion that objectivist and scientist-led research would yield unambiguous answers, towards a notion that farmers can contribute insights, and need to at least partly modify results from on-station research to suit their field realities (Yazman *et al*., 1995; Okali *et al*., 1994). In academic terms, this represents a change from a static and top-down tendency to more post-modern approaches (Leeuwis and Pyburn, 2002). The difference between the static and dynamic notions also reflects a shift from thinking in terms of development to a final 'equilibrium' state towards one with continuous change (Behnke *et al.*, 1995; Hodgson, 1996). A similar contrast exists between the positivist notion that aims at exactly describing a system, its boundaries and goals on the one hand, and the more constructivist paradigms on the other hand, recognizing simultaneously its interconnectedness, side effects, and implications in the context (Röling, 1994, 1996). From initial emphasis on better fitting of particular technologies, it now looks into niche suitability with participatory approaches (Ørskov, 1999), and use of technologies to achieve broader goals than before (i.e., watershed development rather than milk yield).

Participatory approaches are now widely used in development and research projects. Community participation in all stages of a project cycle can lead to more efficient research and development. Participatory research and development fruitfully uses indigenous knowledge, skills, and local resources. It also builds up the confidence, mutual trust, sense of ownership, sharing of skills and knowledge and it empowers more stakeholders, including researchers (Chambers, 1994a, c). It is expected that greater farmer participation in the situation analysis, problem identification, the choice of possible solutions, design and implementation of farm trials, identification of indicators for outputs and evaluation will increase the value of research for farmers, researchers and policy makers (Waters-Bayer and Bayer, 1994; Sumberg *et al*., 2003). There appears to be no sharp boundary between where FSR stops and farmer participatory research starts: in the process they overlap (Collinson, 2000; Defoer, 2002).

Limited successes in development programmes in the past have contributed to emergence of the new concept of 'sustainable development', to revise the current strategies for rural development. Awareness within the research community has increased over the last decade that both, quantitative methods with a strong future-orientation and more qualitative process-oriented studies with a strong emphasis on context, have a role to play in promoting management strategies and policies aimed at sustainable land use. More specifically, there is an increasing call for multi-scale approaches and integration of natural and social science approaches. The eco-regional research approaches (Rabbinge, 1997; Horton *et al*., 2002) fit in this perspective. Sayer and Campbell (2001) indicate the need for interdisciplinary research aiming at sustainable management of natural resources, emphasizing both the role of human actors and social and biophysical research methodologies. The need and notion of sustainable development has in the last decade strongly influenced the R&D agenda.

Development is a neutral term, but it tends to describe ‘a process that brings positive change and improves the quality of life in a desired manner’. Some of the well recognized definitions for sustainable development are (WCED, 1987): “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs”; (FAO, 1987) “Sustainable development is the management and conservation of the natural resource base, and the orientation of technology and institutional change in such a manner as to ensure the alternate and continued satisfaction of human needs for present and future generations. Such developments conserve land, water, plant and animal resources, are environmentally non-degrading, technologically appropriate, economically viable and socially acceptable.” Last but not least there is the notion that “Sustainable development is a process of simultaneously ensuring continuation of the economic, social and ecological basis of human life” (Lele, 1991).

Sustainable development widens the scope of rural development, abstracting from the commodity-focused concepts to ‘rural’ and ‘agriculture’ (Carney, 1998; DFID, 1999). Livelihood approaches with their holistic outlook, generate their own set of definitions of constraints and opportunities and their feasibility. This helps in organizing the various factors that constrain or provide opportunities for development and their relations. This approach works with the people, supporting them to build upon their own strengths, and realize their potential, while at the same time acknowledging the effects of policies, and institutions, external shocks and trends (Carney, 1998; DFID, 1999; Baumgartner and Högger, 2004). It is too early to draw final conclusions on this approach, as its wider applications and impacts are yet to be assessed.

The study reported in this thesis has its roots in the FSR tradition of the 1990s, characterized by notions such as farming, research and systems (Shaner *et al*., 1982; Schiere, 1995). Farming comprises a mix of all components in agriculture, e.g., crop production, animal production, forestry. It may be combined with off-farm activities, such as production of handicrafts, a small shop, blacksmith, or small oil mill. Research is defined as the collaborative activity of farmers, extensionists and formally trained scientists. Research is not confined to the laboratory or experimental stations, but includes farmers' fields, using both qualitative and quantitative methods. System is a term used in various ways. Röling (1994) characterizes a system as: "a construct with arbitrary boundaries for discourse about complex phenomena to emphasize wholeness, inter-relationship and emergent properties".

Many different forms of FSR can be distinguished, and the classification of Simmonds (1986) for example, distinguishes three types (a) academically-oriented work (FSR *sensu strictu*), (b) development-oriented work (FSR&E) and (c) work oriented towards the development of entirely new farming systems (NFSD). This thesis mainly uses the development-oriented type of work, i.e., FSR&E. It also uses some tools from FSR *sensu strictu*, such as surveys and technology fitting. In essence, FSR&E consists of the following steps (based on Shaner *et al*., 1982; Norman *et al*., 1995):

1. Identification of the action area with its various recommendation domains, e.g., by using maps and transects (this Chapter);
2. Identification of local problems, e.g., by using participatory rural appraisals, meetings with local groups and stakeholders (Chapter 2);
3. Identification of possible interventions and/or new research questions, through consultation of literature, farmers' experiences, monitoring and modelling (Chapters 3, 4, 5 and 6);
4. Field testing of innovations to identify suitability and/or modifications (Chapter 6).

Rationale of the study and objectives

Livestock production systems are complex and dynamic and are affected by many factors, including farmers' access to resources, knowledge and skills, consumer demands, national and international policies, and social aspects (De Jong, 1996; Devendra, 2000; Paris, 2002). Attention to socio-cultural aspects implies that animals mean much more than only a means of producing milk or offspring; draught, manure, security, prestige, and other social functions are often overlooked, while they are central to the notion of the metaphor '*kamdhenu*', signifying the cow as a 'mother' that provides everything. The admittedly low production in terms of milk yields is often linked to problems of limited availability and low quality of feeds or to type of genetic material, health and management. Various options to solve the problem of low quality feeds or genetic potential have been proposed and tested in both the laboratory and the field. They include introduction of imported breeds, exotic forages, supplements, improvement of poor quality crop residues by various treatments (Chapter 2). However, this type of scientists' recommendations and experiments tend to have had limited impact on production at farm level (Udo, 2002). Too often, scientists and policy makers lacked the proper perspective on the local resources, the environment and the needs of the farmers (Van de Ban and Hawkins, 1988; Mahadevan and Devendra, 1985; Chambers *et al.*, 1989; Fresco and Westphal, 1988; Röling, 1996; Collinson, 2000). Most of the available technologies are, however, only appropriate for specific groups of farmers in Gujarat, i.e., they are system-specific and their usefulness depends on local resources, needs, skills and indigenous knowledge.

This study started with the following objectives:

- Identify criteria that can be used in selection of appropriate livestock technologies for mixed farming systems in Gujarat;
- Identify methodologies to select technologies for application at farm level;
- Identify differences in methods of selection and application of given technologies in the mixed farming systems that are being studied.

The thesis is based on experiences with the methodologies and results of the livestock development programmes implemented by BAIF in Gujarat. Starting with cross-breeding of cattle, its livestock development programmes have become more comprehensive by inclusion of supportive activities such as fodder production, agro-forestry, farmers' training, extension, health care, feed improvement and development of other animals, such as buffaloes, goats and poultry. Simultaneously, the development activities in cropping and forestry were incorporated into the programmes, wherever felt needs were recognized in those areas. So, while working on the thesis, emphasis shifted from finding constraints and solutions towards an understanding of the dynamics of livestock development for mixed farming systems in Gujarat.

The structure of the thesis

This thesis is divided in five major sections. The first section presents demographic and agro-ecological information on India as a background for BAIF and its activities. It characterizes prevailing livestock systems using secondary data and FSR&E methodologies (Chapters 1). It then provides a situation analysis, problem identification and opportunities in livestock production, using methodologies such as zoning, transect mapping and scoring (Section 2). The third section consists of two chapters that describe the impact of crossbreeding in the mixed farming situation in Gujarat, in different zones and for different social groups. Section 4 focuses on the design, fitting and testing of technologies, describing the use of three forms of simulation modelling. By doing so, it examines the usefulness of feeding and breeding interventions for different conditions. It evaluates the interventions with respect to several aspects, mainly technical feasibility and economic viability but it also raises the issues of social aspects and farmer's perceptions. Modelling is presented as complementary to on-farm-experimentation in Chapters 5 and 6. These chapters describe the experiences of narrative, quantitative/qualitative results of on farm experimentations at animal, farm and watershed level. It considers the modification in farmers' conditions and their perception of interventions in terms of production, cost-benefit analysis and adoption. The fifth section (Chapters 7 and 8) consists of illustrations on BAIF's work which has experienced major paradigm shifts in terms of its approaches. These are compared with similar ones from the international scene and wrapped up with a discussion and conclusions. The final section also discusses cross-cutting issues of hierarchy, systems dynamics, possible tensions between top-down and bottom-up approaches, as well as differences and similarities between agricultural R&D in 'East and West'.

CHAPTER 2

Identification of constraints and options for livestock development: Experiences of an Indian NGO

Summary
Effective development requires identification of local needs and opportunities. Different organizations apply different methods, ranging from top down to more participatory ones, and depending on felt needs arising from system changes in time and space. This chapter describes the experiences of BAIF (BAIF Development Research Foundation, an Indian Non Governmental Organization). It starts by giving some details on BAIF's working area, on changes in the organization itself, and on the FSR&E methodologies it used over the years to identify possible interventions. Participatory tools used in constraint analysis helped to understand the real problems on feed resources, marketing of milk, farmers' felt needs for breeding, and planning and implementation of technologies such as urea supplementation, feeding of gotar and leuceana leaves and breeding of livestock. It was also a learning experience for the extension workers and researchers. The focus is on work in livestock development, increasingly as part of larger issues in rural development such as poverty alleviation, food security, natural resource management, and quality of life.

Introduction

Awareness about interconnectedness of (sub-) systems and regional differences among agricultural systems were the main reasons that various forms of Farming Systems Research (FSR) were developed in the 1960s and 1970s, among others by the research centres of the Consultative Group on International Agricultural Research. Initially, FSR primarily aimed at better identification of the recommendation domains in which given technologies, developed on-station, could be usefully applied (Amir and Knipscheer, 1989). Essentially, it was a top-down approach aimed at ensuring continued effectiveness of extension efforts aimed at transferring technologies developed in (inter)national research (Fresco and Westphal, 1988). However, not all the technologies developed and tested on-station addressed the farmers' needs that arose in the course of the development process. During the 1980s, growing interest developed in understanding local needs, ultimately changing the development agencies' approach from top-down to bottom-up. This resulted in development of participatory approaches that aimed at identifying interventions to solve local problems in consultation with stakeholders (Chambers *et al.*, 1989; Chambers, 1994a, b, c; Röling and Leeuwis, 2001). Proper identification of local needs and opportunities is essential for the design of successful development programmes. Various methods and approaches are now available, and the choice may depend, among others on location, type of organization and local conditions (Shaner *et al.*, 1982; Chambers, 1997; Uvin *et al.*, 2000; Röling and Leeuwis, 2001).

The experiences of BAIF (BAIF Development Research Foundation, commonly referred to as BAIF), an Indian NGO (Non Government Organization) illustrate issues that can be useful for others in the field. BAIF has over the years used various participatory approaches for the identification of problems and opportunities in rural development, with emphasis on livestock development. Based on in-depth knowledge of life in one village in the 1970s, BAIF initiated a cross-breeding programme in a number of villages for the genetic improvement of cattle, using frozen semen (Rangnekar, 1989; Mangurkar, 1990). Application of this technology was then expanded to other states, but it was realized after some time that the requirements of each village community were specific and different. This chapter narrates the experiences of BAIF in identifying suitable interventions and approaches to tackle issues in livestock development.

Description of BAIFs working region: Gujarat (India)

General

Location, topography, soils, and land use patterns

Gujarat is situated on the west coast of India between 20.1° and 24.4° N and bordered by the Arabian sea on the West, by Pakistan and the state of Rajastan in the North and Northeast and the States of Maharashtra and Madhya Pradesh in the East and Southeast (Figure 1). Of the total population of over 51 million (census 2001), about two thirds live in rural areas (Anonymous, 1997). The average population density is around 211 persons per km^2 (Anonymous, 2000b), but with a great degree of variation: from thinly populated in the northeast (<100 persons per km^2) to densely populated in middle-Gujarat (>400 per km^2). Gujarat, with a total area of 196,000 km^2, is mainly agrarian in nature, with 50% of its area under cultivation, 10% under forest, 4% under grazing and 23% is wetland, the remaining area is under miscellaneous use (Anonymous, 1995). Agriculture contributes almost 26% to the State GDP of which livestock contributes 31% (Anonymous, 2000e). Livestock is an integral part of mixed farming systems in Gujarat, as in other parts of India. Livestock keeping is a secondary occupation for most large (over 2 ha of land, less than 20%) farmers, but is the primary source of livelihood for poor and landless farmers (14%).

Rainfed mixed farming occupies most of the 9.67 Mha of cultivable land, of which 23% is under irrigation. The topography of the State varies from plains in the north-west to undulating hilly areas in the East.

The soils are shallow (<25 cm) to deep (>75 cm) black, coastal alluvial to sandy loam. Major crops are maize, sorghum, cotton, pearl millet, groundnut, pulses and rice (Ghosh, 1991).

Climate and rainfall

Temperature and rainfall vary strongly across the State. The north has an arid climate, the south is sub-humid, while the remainder of the State is characterized by semi-arid conditions (Figure 2). Mean daily temperatures vary from 15 (January) to 42 °C (May), reaching maxima of up to 47 °C at some places in the arid region. Average annual rainfall varies from 300 to 1500 mm, but rainfall is erratic, with large inter-annual variations, while frequent droughts and long dry periods are common. About 95% of

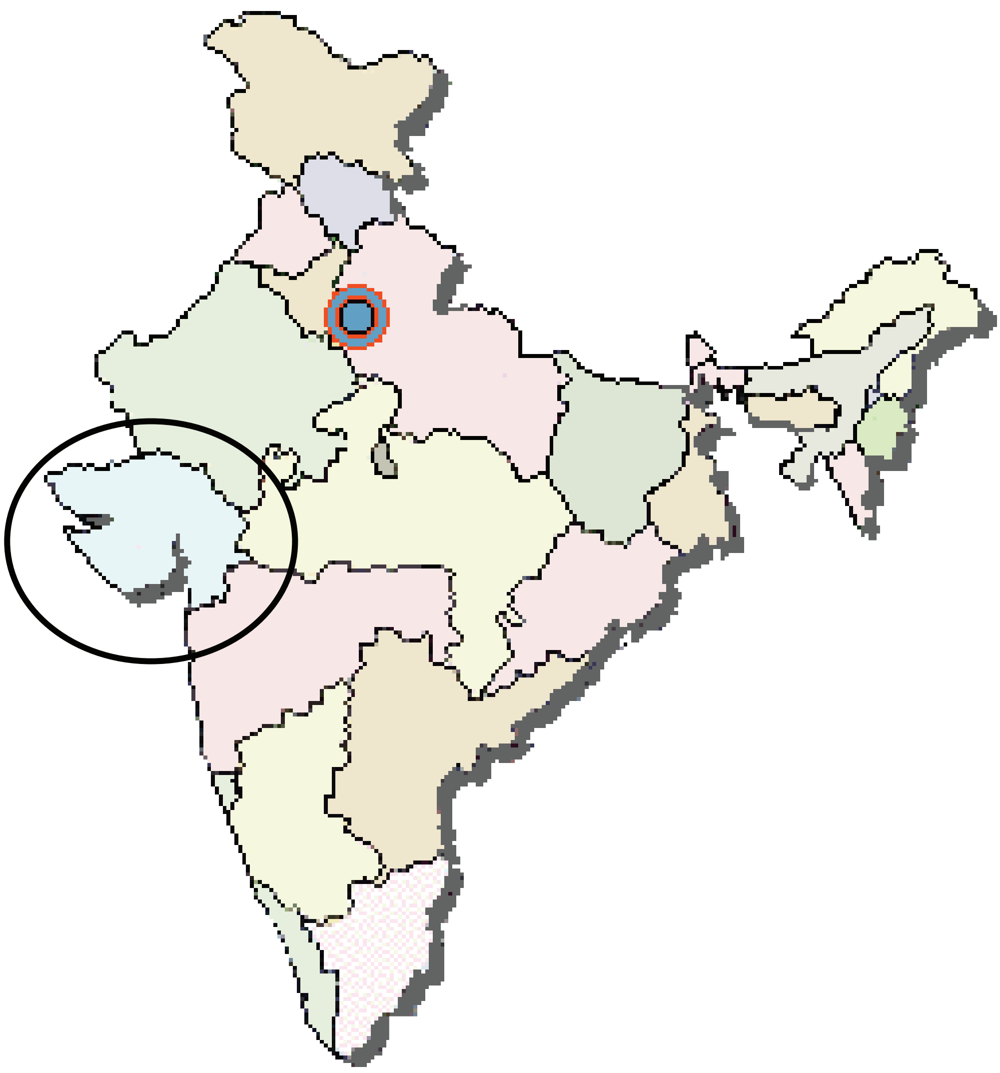

Figure 1. Map of India, with the State of Gujarat in the West.

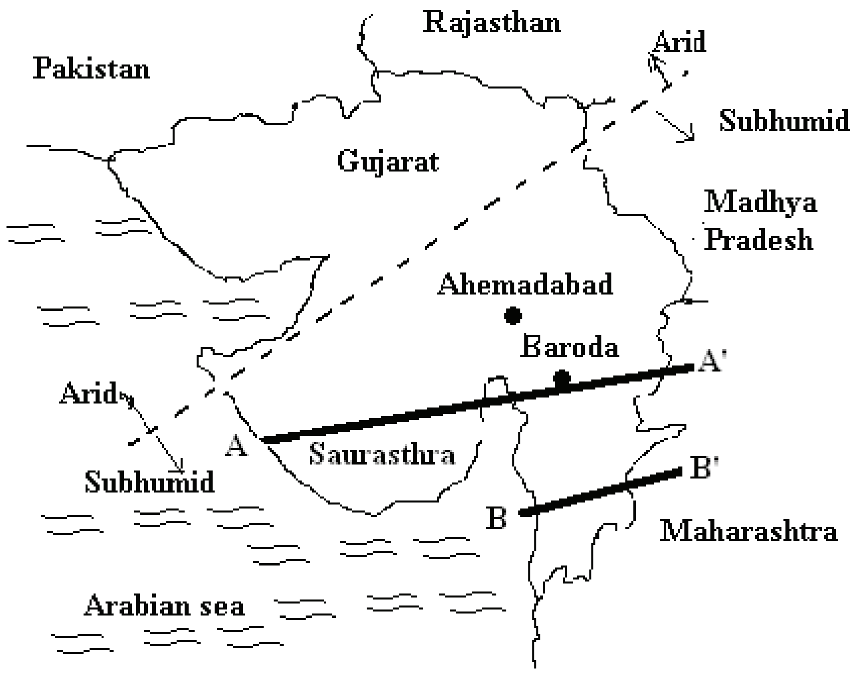

Figure 2. Climatic map of Gujarat, with Transect I (B–B') and Transect II (A–A').

total rainfall is received during the monsoon from mid-June till September (Ghosh, 1991); winter (dry and cold) extends from mid-October to February, summer (hot and dry) from March to June.

General agriculture

The rural areas in Gujarat on which we focus, are characterized by subsistence-oriented small mixed farms. Cotton, millets, groundnut, and wheat are the major crops of Saurashtra region; millets, rice and pulses those of middle Gujarat and rice, mango and sugarcane those of south Gujarat. Livestock are an integral part of the farms. Average land holdings are less than 2 ha, with 3 to 6 animals, predominantly cattle, followed by buffaloes, goats and sheep. Livestock are kept for milk, draught, manure, fuel, as a source of cash for emergencies, and for social reasons (Apte, 1989; Singh *et al.*, 1995; Devendra, 2000).

Social structure

Gujarat has a mixed population of different ethnic groups, such as tribals and non–tribals, and of different religions such as Hindu, Jain, Muslim, Sikh, Parsi and Buddhist. Around 15% of the total population is tribal, a distinct ethnic community of Indian origin, Dravids, living in socio-economically unfavourable conditions, with the lowest literacy rate (less than 21%) in the State. The tribals live in remote areas around forests and are dominant in the East and South of the State (Masawi, 1988), and have different traditions and customs than those of non-tribals. They recently started farming (about 6–7 decades ago), where earlier forest products comprised their major source of livelihood. About 6% of the total population is scheduled cast, a socio-economically backward and less favoured group, suppressed by the cast system within the Hindu population.

Animal Production Systems

Livestock population

With a total livestock population (2003) of 20.61 million (Anonymous, 2003b), average livestock density in Gujarat exceeds one animal ha^{-1}, with the highest value in the rainfed mixed farming area of middle-Gujarat (1.73 animals ha^{-1}) and the lowest in the arid zone of northeast Saurashtra and Kutch (0.57 animals ha^{-1}). The total cattle population of Gujarat is 7.4 million and that of buffaloes 7.1 million (Table 1).

Gujarat is one of the few States in the country with such distinct milk and dual purpose cattle breeds as Gir (predominantly in Saurashtra) and Kankrej (predominantly in the north) and buffalo breeds such as Surti (predominantly in the south), Mehsani (predominantly in north-central) and Jafarabadi (predominantly in Saurashtra). Kankrej bullocks are preferred for draught purposes by the farmers because of their pulling capacity and speed, while their majestic look earns them prestige, and Gir are preferred for both milk and draught purposes.

Most of the cattle and buffaloes belong to defined breeds, while non-descript breeds comprise around 20% of the cattle and only 1.5% of the buffalo population. The breed distribution of animals indicates a higher proportion of non-descript cattle breeds in

Table 1. Livestock population (millions) of Gujarat (Anonymous, 2003b).

CATEGORY	1951	1961	1972	1982	1992	1997	2003*
Cattle	5.34	6.56	6.46	6.99	6.80	6.74	7.40
Buffalo	2.51	2.91	3.47	4.44	5.26	6.28	7.10
Total bovines	7.85	9.47	9.93	11.43	12.06	13.02	14.56
Sheep	1.58	1.48	1.72	2.35	2.02	2.15	2.06
Goats	2.32	2.22	3.21	3.30	4.24	4.38	4.54
Other livestock	2.18	0.28	0.24	0.37	0.26	0.41	0.48
Total livestock	13.93	13.45	15.99	17.45	18.59	19.93	21.64
Poultry	1.13	2.05	2.74	3.57	5.65	7.23	8.15

* provisional 2003.

the centre (45.1%) and south (57.8%), as these are not traditionally breeding tracts of Gir or Kankrej cattle, whereas small numbers of non-descript buffalo breeds can be found in the north (3.3%).

Livestock dynamics in Gujarat

Over the last fifty years, the livestock population has witnessed many changes. Some species, in particular buffaloes and poultry, have shown a fast growth in this period. The total livestock population increased by 1.14% y^{-1} (excluding poultry), a trend similar to that at national level (Chapter 1), but the buffalo population increased faster (3.6% y^{-1}) than that of cattle (0.77%), and the goat population increased faster (1.9%) than that of sheep (Figure 3). Crossbreds comprised 8.6% of the cattle in the year 2003, and increased by 4.5% y^{-1} in the period 1992 to 2003, while indigenous cattle increased by 0.6% y^{-1} (Anonymous, 2000b). The drastic decline in male population (2.2% y^{-1}) contributed to this slow growth, a trend also observed at national level (Kelley and Parthasarathy Rao, 1994). This change in type of animals may be attributed to farmers' preferences for crossbreds and buffaloes for milk, and the increasing use of tractors for agricultural operations and transport, reducing the need for draught animals (Vaidhyanathan *et al*., 1979; Kelley and Parthasarathy Rao, 1994). During the 1970s and 1980s, there was only a marginal growth in the bovine, cattle and sheep populations, and a decline in buffalo population, primarily because of the severe drought during this period.

Milk production

Total annual milk production was 6.09 Tg in 2002–2003, comprising about 7.1% of the national total, with 5.1% of the total national cattle and buffalo population (Anonymous, 2003c). The human population of Gujarat State comprises 4.5% of that of the country, while per capita availability of milk is 321 g d^{-1}, i.e., 40% above the national average of 230 g d^{-1} (Anonymous, 2003c). This is attributed to the presence of the well-defined breeds in the State. However, daily milk production per animal seems to be stagnant in the State (Table 2). Although, the dairy cooperative movement has done pioneering work and has strong roots in the State, its distribution is uneven. Twelve milk unions procured 1.86 Tg of milk from 2.28 million milk producers during 2003 (Anonymous, 2003c). Gujarat has good networks in the middle, southern and northern districts, but weak ones in the western parts (Saurashtra). Two thirds of the total milk produced is being collected by the unorganized sector.

Feeding and housing

The livestock feeding system is mostly that of semi-stallfeeding, and the ration consists basically of residues of sorghum, maize, paddy, wheat, groundnut and pulses. Livestock are fed green forages during the monsoon, small quantities of weeds from irrigated fields during the dry season, and limited quantities of damaged grains and concentrates (Figure 4). Cattle and buffaloes are grazed for 4–8 h d^{-1}, depending on the season. Green fodder cultivation is very limited and restricted to farmers having

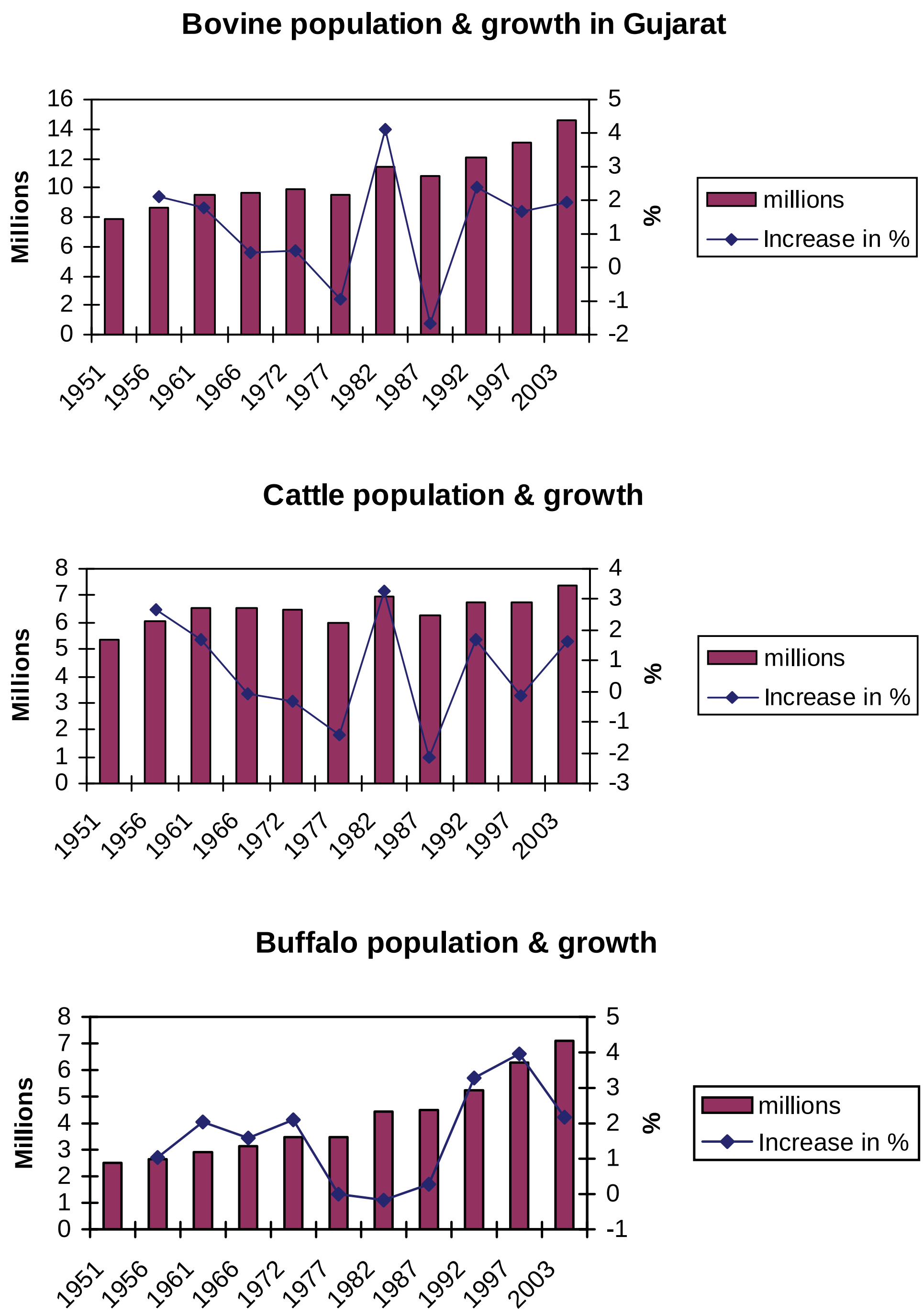

Figure 3. Dynamics of the bovine, cattle and buffalo populations in Gujarat.

Table 2. Milk production estimates of different species in Gujarat (Anonymous, 2002).

Year	Average daily yield (kg)			
	Cow		Buffalo	Goat
	Indigenous	Crossbreds		
1990-91	2.70	8.18	3.74	0.20
1995-96	2.94	7.90	3.81	0.21
1996-97	2.95	7.94	3.91	0.21
1997-98	2.89	7.96	3.88	0.21
1998-99	3.00	8.05	3.96	0.21
1999-00	3.03	7.81	3.99	0.35
2000-01	3.01	7.35	3.88	0.35
2001-02	3.06	7.93	3.98	0.36

access to irrigation facilities in the winter season. Supplementary feed in the form of concentrates is offered to milk-producing or working animals. Concentrates (compound feeds, produced commercially by cooperative and private feed factories) are available where milk cooperatives are well established, i.e., in the middle and the south of Gujarat. In some areas, limited quantities of a mix of home-made (mix of damaged grains and broken pulses) and compound feeds are offered. However, in general, quantity and quality of available feed resources are inadequate to meet the animal feed requirements. Livestock is housed mostly in katcha (mud earthen walls), thatch-roofed sheds in the backyard, few well-off farmers use packka sheds (with cement and bricks) with tin roofs. Cattle sheds are floored generally with murum (broken stones/rocky soils) or sand with soil, some may be equipped with wooden mangers.

Identification of problems and opportunities in livestock production

BAIF’s work in cattle development was initiated in Maharashtra State and encouraged by its success, was subsequently introduced into other states such as Gujarat (Mangurkar, 1990). In Gujarat, the activities involved introduction of artificial insemination, crossbreeding and fodder packages. The approach was of a ‘blue-print’ commodity-oriented, top-down nature. Despite substantial subsidies and Government support, initially only few farmers (about 15–20%) did adopt these technologies.

BAIF then had to revert back to more participatory methods that it had implicitly used as a basis for its initial success, by involving the communities in a bottom-up approach. Some of its staff members had come across these methods in literature, workshops and training courses (Rangnekar *et al.*, 1993a). Many of them started

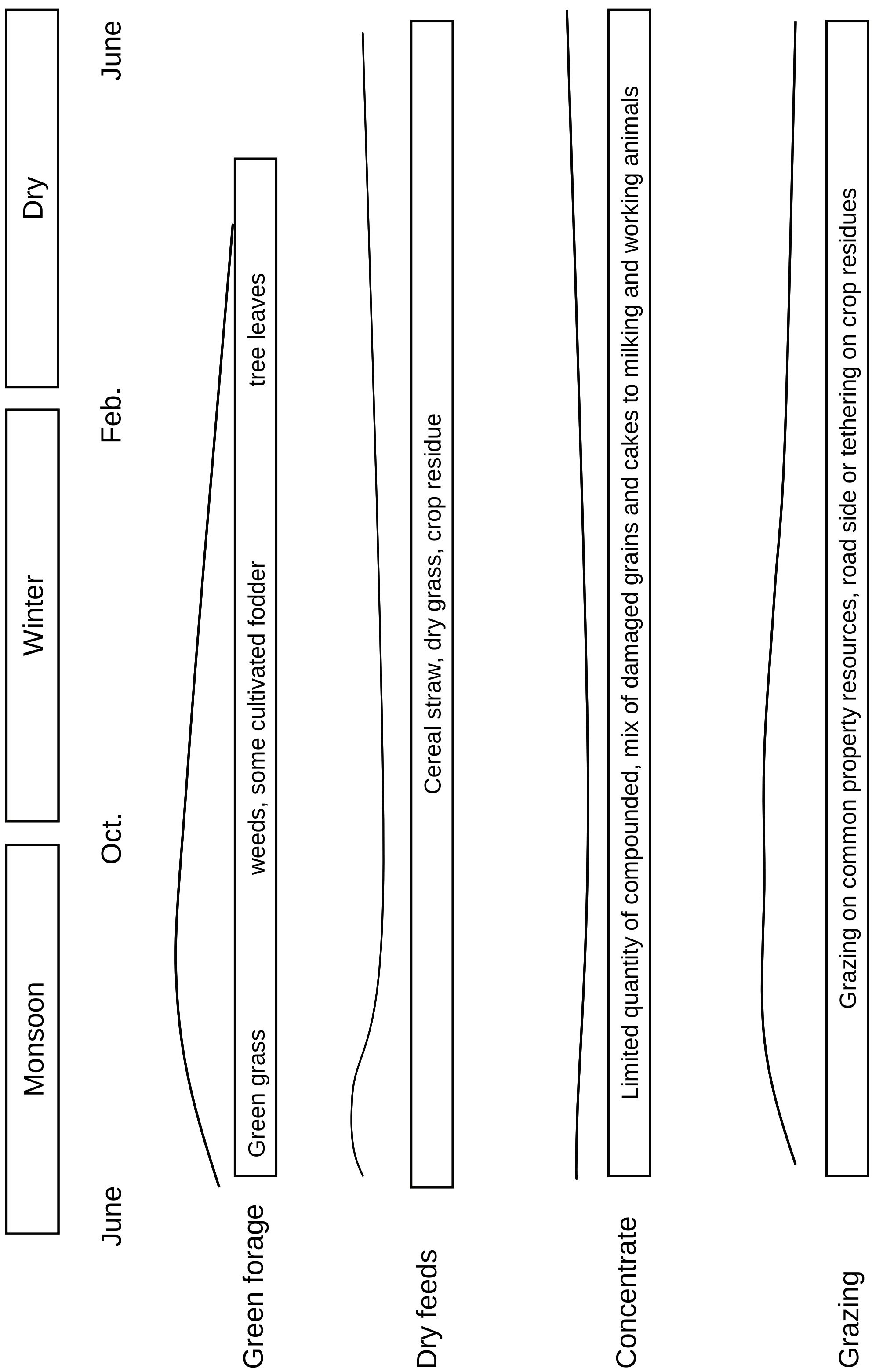

Figure 4. Livestock feeding calendar (based on discussions with BAIF field staff).

noticing that ‘commodity-driven’ approaches with emphasis on ‘across the board’ introduction of artificial insemination, crossbreeding and fodder packages, did not yield the expected success. In fact, some of BAIF’s programmes had already gone back to its original concept of community-based programmes, where livestock development was a tool for the creation of gainful self-employment through crossbreds, similar to mango cultivation, and not a goal in itself (Hegde, 2001; Anonymous, 2001b). Hence, BAIF turned to FSR with special emphasis on livestock development, in an effort to introduce a bottom-up approach, involving the community in identification of problems and interventions. In the following a description is given of various issues and results of the implementation of FSR&E techniques.

Zoning, mapping, transects and identification of areas for action

Choice of criteria for ‘zoning’
Since climatic conditions, especially its effect on water availability of a region, largely determine its suitability for different crops and livestock, attention was paid to agro-ecological zonification (FAO, 1978). In zoning, maps depicting agro-ecological zones support identification of suitable crops and livestock species to develop farming systems for increasing agricultural and livestock production with optimum feeding regimes.

Many zoning approaches based on agro-ecological criteria exist at national scale in India. Jain and Dhaka (1993) reviewed the different typologies of land use for agricultural development in India, illustrating a staggering variation. Zoning criteria used are size of the land holding, soil type, erodibility, market access and distance to the city. The criteria for classification, based on macro-regions, are insufficiently detailed for operational planning for small mixed crop-livestock farms. Moreover, agro-ecological zoning for cropping systems is not the same as for livestock development, among others because of the wide variation in distribution of breeds of livestock, types of animals, and availability of feed resources at both regional and farm level.

National criteria guided the discussions at BAIF Head Office which operates mainly at national scale. Regional BAIF offices, however, need a finer ‘grid’ and other criteria, depending on their mandate and the objectives of the sponsors. In fact, problems and priorities change as one moves through system levels, from national to state to district level and further. For example, with respect to livestock development, the composition of the herd in terms of types and breeds of animals in Gujarat State is different from that at national level. BAIF initiated a breeding programme aimed at increasing milk yield of livestock through crossbreeding. The BAIF programme in Gujarat, therefore, adopted state level zonations that combined administrative and agro-climatic criteria, as a basis for discussions with local district and State government officials.

Development agencies applying a top-down approach will use zoning and/or mapping to scan the national or regional maps for areas suitable for a particular purpose, such as milk or meat production. Groups that work on poverty reduction intend to look for pockets with specific social characteristics. Patil *et al.* (1995) demonstrated by using transects and mapping that zoning for planning research and development can be performed at the level of the state, district, taluka (block), village or farm, to address the specific constraints at different specific levels. Figure 5 shows a village resources map drawn by village people with roads, houses, temple, school, village pond, crops and grazing lands, and common property resources.

For the purpose of this study, three agro-ecological zones in the Gujarat Plains and Hills regions across a transect in the NARP-ICAR agro-climatic map were selected (Figure 6; Ghosh, 1991). This was based on the operational area of BAIF, in support of planning development activities for the three zones of the Gujarat Plains and Hills regions during a workshop in 1992 under a project on feeding of crop residues as part of a comprehensive livestock development programme (De Boer *et al.*, 1994a; Yazman *et al.*, 1995). The zones were:

- South Gujarat: irrigated mixed farming with a strong market infrastructure (Zone 1 in the Ghosh classification);
- Central Gujarat: rainfed mixed farming with a strong market infrastructure (Zone 3 in the Ghosh classification);
- Saurashtra: rainfed mixed farming with a weak market infrastructure (Zone 6 in the Ghosh classification).

The transect was the basis for Table 3. Some socio-economic aspects, such as access to markets, infrastructure, and biophysical aspects like climate and soils were included in the description of the zones. However, other socio-economic aspects, such as caste, gender and traditions are hard to include in geographical maps.

Geographical precision is less critical at farm than at regional level, and factors such as family size, social status, income, literacy rates and the role of women can be included in tabulated form with a graphic presentation at state, regional or district level. Lack of reliable data and strong local variation in such factors imply that they cannot easily be mapped. These characteristics, however, are as relevant as biophysical factors for extension and development programmes (De Boer *et al.*, 1994b).

Results

Transect I (Figures 2 and 7) passes through the Surat and Valsad districts of south

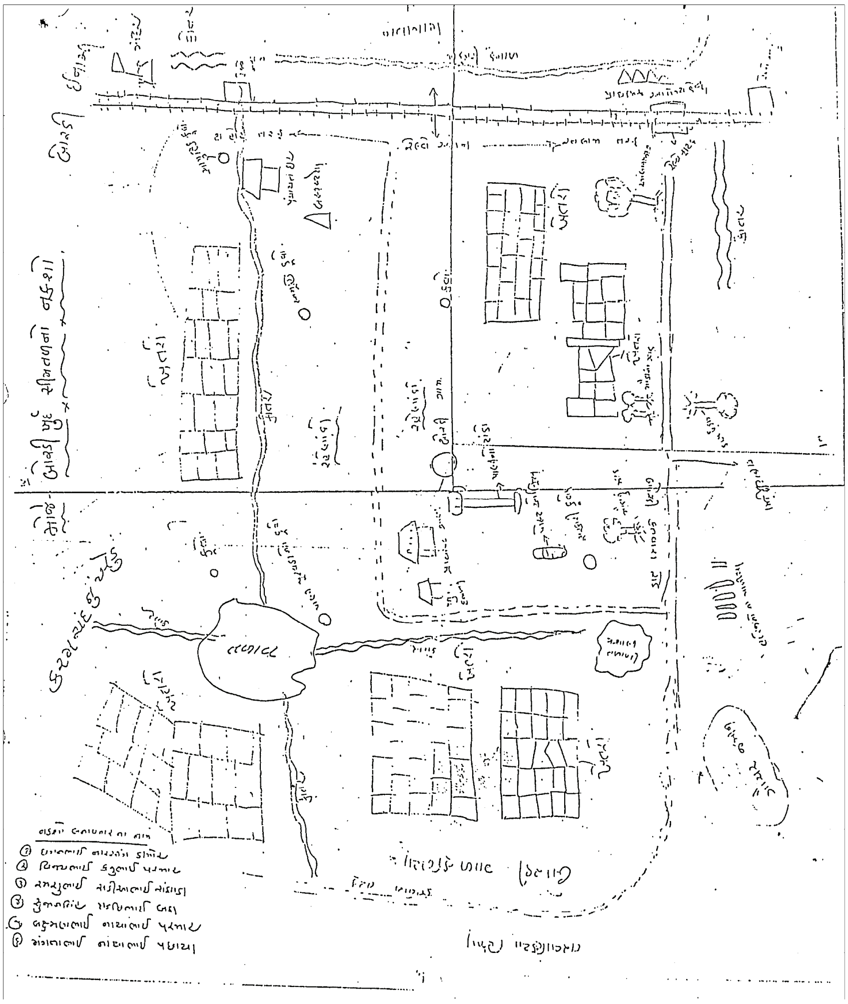

Figure 5. Resource map by the farmers of the village of Boradi (based on Anonymous, 2000d).

Table 3. Criteria for system classification (based on discussions with BAIF staff 1999).

Criterion	Intended development action
Social group	Targeting for development of special groups (categories) economically weaker, below poverty line/ tribals
Resource base	
Land holding	Landowners for fodder development programmes; landless agricultural labourers for supplementing their income through livestock rearing
Irrigation	Cropping pattern
Type of livestock	Crossbreeding of cattle
	Buffalo breeding
	Improvement of small ruminants

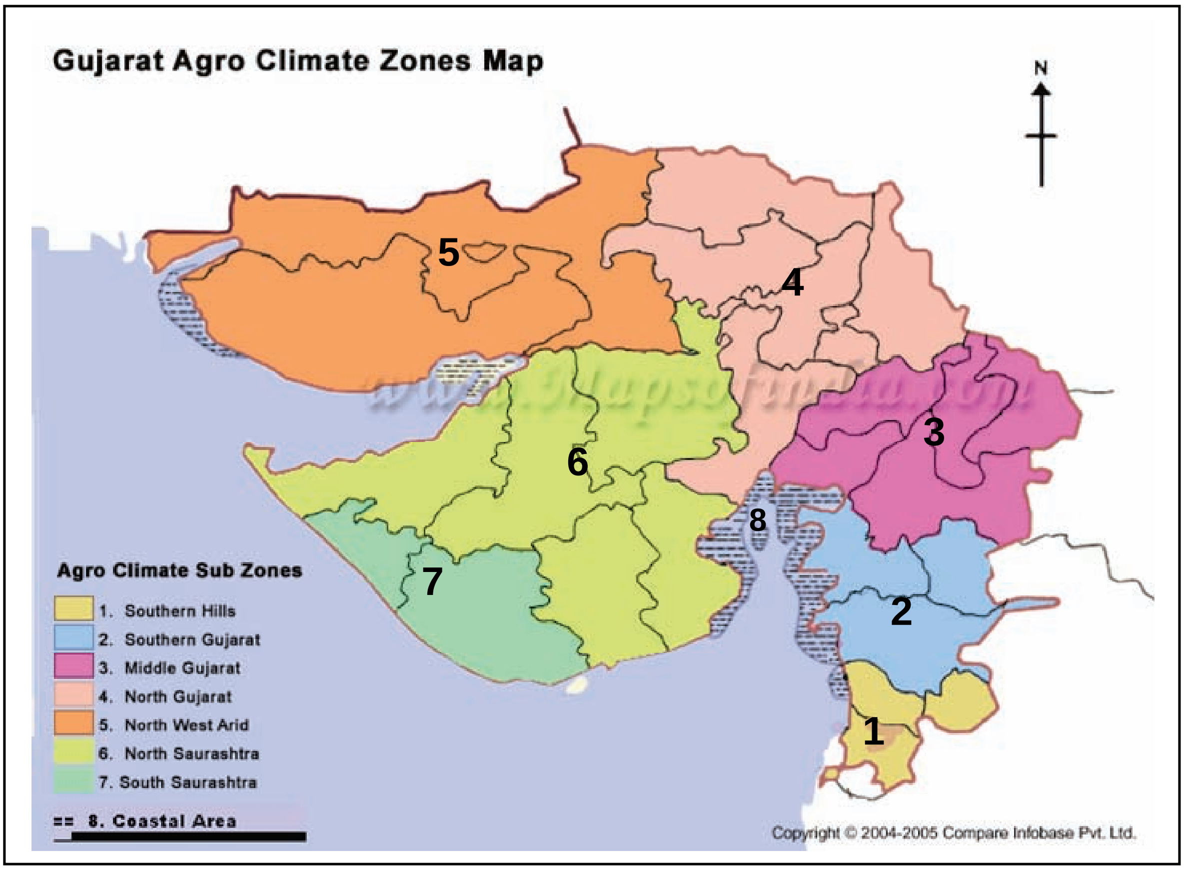

Figure 6. Agro-climatic regions of Gujarat (Zone 1–8).

Gujarat (Zone 1) and transect II through the districts of Saurastra (Zone 6) and middle Gujarat (Zone 3; see Figure 2). South Gujarat is characterized by high rainfall (1000 to 1500 mm annually); along transect II, rainfall increases from West (Zone 6) to East (Zone 3). Zone 6 has a small pastoralist population, while Zones 3 and 1 have large tribal populations. Labour availability is relatively low in Zone 6 and higher in Zones 3 and 1, whereas strong marketing networks exist in the eastern district of Baroda, Zone 3 and Valsad and Surat districts in Zone 1. Sorghum and pearl millet straw are major sources of feed in all zones. Availability of groundnut haulms declines towards the east (Zone 3), while paddy straw is available from Baroda onwards to the east (Zone 3, transect II) and in Zone 1. In the eastern parts of both transects, forest and grazing land in the hills and valleys are more abundant than in the west. Livestock density is highest in Zone 3, middle Gujarat. Across the transect in all zones, about 50% of the total area is under arable cropping, while fodder cultivation is rare (3–4%). Crop residues are the major source of feed for cattle and buffaloes, although this varies across the seasons. Availability of straw was highest during the rabi season, and low during summer and the early monsoon season, indicating the relative scarcity of fodder during this period in all zones (Table 4).

	Transect A–A'	Transect B– B' South Gujarat
	Saurashtra .. .. Middle Gujarat	coast .. .. hills
Rains		
- amount, mm yr^{-1}	625 1000	1000–1500 (throughout)
- reliability	low & erratic .. ..medium non-reliable	high and reliable (throughout)
Soils	shallow / light black .. sandy light black	coastal alluvial .. .. medium / deep black
Topography	hilly .. plain/flat .. sea .. plain/flat .. hilly	sea .. plain/flat .. hilly
Major social groups	non-tribal .. .. tribal / non-tribal	tribal / non-tribal (throughout)
Livestock		
- density, 10^3 an. ha^{-1}	approx. 1100–1700 (througout)	approx. 1100 (throughout)
- cattle breeds	Gir, X-breds, ND* .. .. ND*, X-breds	ND*, gir, Xbred
- buffalo	Jafarabadi .. .. Surati, ND*	surati, ND
- sheep	Patanwadi. . . . . ND*	-
- goat	Zalawadi. . . . . ND*	Surati (throughout)
Cropping system**		
- major crops	groundnut, wheat, millet, cotton, maize, paddy, cotton, pulses, sorghum	paddy, sugarcane (throughout)
- rainfed	+++ (throughout)	+
- irrigated	– (throughout)	++
Matket linkage	weak . . . . .stronger	strong (throughout)

* ND is non-descript cows, buffaloes, sheep and/or goats;

** ++: major cropping system; + : second cropping system; – : hardly present.

Figure 7. A zoning exercise represented in a transect across three agro-ecological zones at state level in Gujarat.

Participatory Rural Appraisals

Participatory Rural Appraisals (PRA) are commonly used tools to assess and analyse the local situation and its complexities at farm, village or regional level (McCracken *et al*., 1988). PRAs are a step towards further specifying at micro level the zoning at village level, to assess local characteristics, not readily available from the transects, such as social structure, customs, caste and access to land. A PRA basically includes an elaborate visit to the areas defined in the zoning exercises. It evolved from surveys with the use of lengthy questionnaires, via the more top-down oriented Rapid Rural Appraisal (RRA), involving a quick field visit of a group of experts (Chambers, 1997).

PRAs use tools such as mapping, stakeholder analysis, time scales, ranking and group discussions. They are implemented by multidisciplinary teams with active participation of the local farmers, to assess their needs in rural development and to select interventions based on skills, indigenous knowledge and resources, as well as to prioritize them. Following the zoning exercise, well-designed PRAs were carried out to verify the preliminary findings of the zoning, as a basis for identification of interventions to improve the nutritional quality of crop residues.

One such PRA exercise was carried out in 1993 by a multidisciplinary team, focusing on constraint analysis in Gujarati livestock systems (Yazman *et al.*, 1995). The information assessed on seasonality and variation in feed supply was not new, but helped the teams to better orient the fodder development programmes towards local and seasonal differences.

The results of the PRA also revealed that the Baroda district is characterized by small farm sizes, low literacy rates, and a complex social structure of tribal and non-tribal populations (Table 4). The major problems identified during group discussions and transect walks, were low productivity of the cows, inadequate feed resources, low to moderate unreliable rainfall, lack of infrastructure, veterinary and AI services and credit. Tribals and non-tribals significantly differed in the distribution of work on animal husbandry activities. Milking of cows is always restricted to women in the tribal community, while in the non-tribal communities, men do the milking as well. In sales and purchases of animals, women of non-tribal families play no role, whereas in tribal families, women do participate in these activities. In the Inami Boradi village of Baroda district, a wide gap was identified between the requirements for green fodder, dry fodder and concentrates and their availability. The major constraints identified during the PRAs were low availability of straw, high concentrate costs, restricted labour availability in certain areas of Baroda district and low animal productivity (Table 4).

Village resource mapping exercises showed reduced availability of grazing land on common property resources (CPR), due to encroachment and degradation, thus reducing feed availability (Figure 5). It was evident from the score of the farmers' responses, in both the tribal and non-tribal group that crossbreds were the preferred choice of animal, followed by buffalo, local cow and goat (Anonymous, 2000d; Table 5). Farmers preferred crossbreds, for their higher milk production and the associated income, but they did prefer buffaloes for ghee making, goats for meat, and local cows for better disease resistance.

They were aware of the higher and better quality feed requirements of crossbreds

Table 4. Constraint analysis for straw and multi-production and crop residue feeding systems in three areas of Baroda District, Gujarat State (based on De Boer *et al*., 1994a).

Items	East Baroda	Central Baroda	West Baroda
Availability of straw	Low	Sufficient	Sufficient
Cost of straw	High	Low/Medium	Low/Medium
Type of straw (quality)	Poor	Good	Good
Cost of concentrate	High	High	High
Productivity level of animals	Low	Medium	Medium
Water availability	Sufficient	Sufficient	Sufficient
Storage space	Low	Low	Low
Price of milk	High	Low	Low
Labour availability	High	Medium	Low
Labour cost	Medium/High	High	High
Recommended technologies for testing	Chaffing to reduce waste; urea-treated straw for high producing animals	Urea-treated straw for higher producers; steam-treated bagasse; urea molasses blocks	Urea-treated straw for higher producers; urea molasses blocks

and buffaloes. Services for crossbreeding were demanded by the farmers that selected crossbreds as preferred animal (Table 5), while animal health care and fodder promotion programmes were especially in demand in Zones 1 and 3 (Rangnekar, 1989; Patil and Udo, 1997a, b).

Discussion and concluding comments

Zone-specific information derived from transects and mapping of for instance feed resources, such as common property resources, grazing areas, crops and crop residues has indicated trends in availability and quality of feeds, especially in the dry season, even without extensive surveys. Information from the national and regional level and from the village level transects show similar trends in farm development, such as increases in the crossbred and buffalo populations. Indeed, it is too simple to conclude that areas to be targeted for mixed farming and those for poverty alleviation are different, in reality, there will be overlap: some mixed farmers may be poor, others might be relatively well off. Characteristics of the criteria used for identification of the target areas may differ. Biophysical characteristics of two different zones may be the same, but perceptions of time, cultural boundaries and expectations of life may be entirely different. In a way, BAIF had to re-orient its staff to recognize these

Table 5. Farmers' preference based on the perceptions of the benefits from livestock keeping at village Bordi, District Baroda, Gujarat. Based on PRA conducted in 2000.

	Tribal farmers				Non-tribal farmers			
Preference criteria	Cows		Buffaloes	Goat	Cows		Buffaloes	Goats
	Local	Cross-breds			Local	Cross-breds		
Milk production	**	****	***	*	*	****	**	-
Regular and substantial Income	**	****	***	*	**	****	**	***
Ghee making	**	***	****	-	***	**	****	-
Disease resistance	****	**	***	****	****	***	***	****
Feed requirements								
Concentrates	***	****	****	-	**	****	***	-
Fodder	***	****	****	-	**	****	***	-
Water requirements	**	***	****	*	**	****	***	*
For draft	****	**	-	-	****	*	-	-
Rearing and selling	**	**	_	****	**	**	*	****
For manure	***	***	****	*	**	***	****	*
Choice of animal	**	****	***	**	**	****	***	*

Ranking: horizontally **** first; *** second, ** third, * fourth, - no value.

characteristics to avoid disciplinary blindness. Table 3 lists some criteria for 'zoning' that emerged in a workshop with BAIF staff. It classifies systems based on characteristics that can be useful for different development actions.

Genuinely bottom-up oriented development agencies have a limited choice of area, nor do they care for such choices, because they happen to be somewhere already, in contrast to agencies that work more top-down. For them the 'zoning' process is unavoidable, whether at (inter-)national, regional, local or even farm level.

The zoning and transect approaches were used eventually for screening of technologies aimed at improvements in animal production systems. They supported identification of the most appropriate technologies, such as crossbreeding and indigenous breed improvement in breeding, and supplementation based on local resources and straw treatment in feeding. The technologies and extension messages, such as introducing winter varieties of sorghum and cowpea for fodder to promote fodder production and improve the quality of available feeds, should be designed according to the variability in seasons and regions. Mapping further supported planning and implementation of technologies, such as establishment of silvo-pastoral systems on community land, water harvesting and soil conservation measures at the village level (Chapter 6).

The zoning and transect approaches were also a learning experience for BAIF staff to use these tools for efficient collection of relevant data, for constraint analysis and for identification of economically viable interventions in the short run, using local feed resources and indigenous knowledge. Feeding technology and breeding policy are important, but not always the top priority of every farmer and at every stage of development. Initially, breeding of animals, crossbreeding and calf care were important, but at a more advanced stage, priorities were economic milk production and reproductive efficiency. Development programmes have greater chances of success, if they have the flexibility to accommodate changing farmers' priorities and felt needs in livestock development originating from variations and changes in time and space (Gahlot *et al*., 1993). BAIF continues to monitor the performance of crossbreds in the field as part of a large breeding programme; results are being reported in Chapters 3 and 4 of this thesis.

Based on the results of the PRA, farmers' preference, constraint analysis and available resources, the appropriate feed interventions were identified. The process of constraint analysis and identification of options recognizes issues of different approaches, needs and constraints at different levels of hierarchy and problems of stakeholders, such as limited production potentials and feed resources, and limited purchasing power to buy better feeds at farm level. Suitable interventions were identified in an *ex-ante* analysis and further tested on farm (OFT) for their socio-economic and technical suitability (Chapters 5 and 6).

BAIF used mapping, transects and PRAs in identifying the local problems. They helped to come closer to the reality and perceived needs of the farmers. Eventually these tools were used for screening of the technology for improvement of feed quality and quantity. Not only that, it oriented and trained the BAIF staff but these were used widely in situation analysis and activity mapping in other regions for location-specific development.

Acknowledgements

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CHAPTER 3

The impact of crossbred cows in mixed farming systems in Gujarat, India: Milk production and feeding practices*

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Summary
Holstein Friesian and Jersey crossbreds are being widely introduced in the state of Gujarat in India. This paper examines whether the crossbreds fit into the existing mixed farm systems. Over a period of four years milk-offtake and feeds offered were recorded for 1331 cows at fortnightly intervals. The breed and the amount of concentrates fed contributed most to the variation in milk offtake. The introduction of crossbred cattle has a major impact on smallholder mixed farming systems. Crossbreds produced, on average, 1.8 times more milk than Desi, Gir, and Kankrej cows. They were fed 1.4 times more concentrates, and about 1.2 times more green and dry feeds than local cows. The major limiting constraint is the quality of the roughages offered. Farmers with crossbreds try to adjust their feeding of concentrates according to the needs of their cows. On tribal farms, local cows produced less milk than on non-tribal farms, whereas crossbreds produced the same amount of milk on both tribal and non-tribal farms. Crossbreds fit into the farming systems of both tribal and non-tribal farmers. The differences in agro-climatic characteristics between different areas in Gujarat were not reflected in differences in milk offtakes.

Keywords: Cattle, Crossbreeding, Milk offtake, Feeding, Mixed farming, India.

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Introduction

In Gujarat, on the West coast of India, cattle are the most important type of livestock on the traditional crop livestock smallholder farms. Cattle are kept for milk, draught, manure, and as security in case of crop failures. The total cattle population is about 6.24 million. The state can be divided into different agro-climatic zones, on the basis of its climate and soil types, for planning location-specific research and development programmes (Ghosh, 1991). About one-sixth of the farming households belongs to tribal groups; these socio-economically less favoured groups have low literacy rates (21% *versus* 50% for non-tribals), and live mostly in and around hilly forest areas, so-called tribal areas, in the Eastern and Northeastern part of the state (Masawi, 1988). Preliminary results of a farm survey indicate that tribal farmers farm, on average, only half of the crop land of non-tribal farmers and their farm income also is about 50 per cent less than that of non-tribal farmers. The agricultural development programmes in Gujarat are targeted at the different agro-climatic zones and social groups.

A baseline survey (done in 1988) indicated that around 75% of the rural households keep cattle and that animal feeding and management practices are some of the constraints to increase livestock production levels in the mixed farm systems in the area, in addition to the common problem of underemployment. Still, the farm survey showed that livestock contributed substantially to farm income: 32% and 20% for tribals and non-tribals, respectively.

The BAIF Development Research Foundation is an NGO (non-governmental organization) that carries out cattle development programmes directed at promoting the socio-economic development of the less favoured sections of society. Back in 1985, BAIF opted to introduce crossbred cattle to increase the income of smallholder farmers, since milk is considered to be the most important contribution of livestock to regular cash income, particularly for the farmers with limited or no land (Mangurkar, 1990; Patil *et al.*, 1993). Cattle can provide employment opportunities to the extent of 80 to 140 man-days per cow per year (Apte, 1989; Mangurkar, 1990). The introduction of cross-bred cattle also provides a basis for establishing rapport with the farmers and an entry point for extension activities (Rangnekar *et al.*, 1993a). Therefore, each farmer who requested crossbred cattle was supplied with semen from Holstein Friesian or Jersey bulls to inseminate his cows, irrespective of the specific conditions in the various farming systems.

It is generally accepted that crossbred cows can produce considerably more milk, but the use of crossbred cattle in Indian farming systems is also queried because of the extra feed needed, and doubts about whether such cattle fit into existing mixed farming systems (McDowell, 1983; Rao *et al.*, 1995). There is, however, no detailed information available concerning the performance of crossbreds in different farm systems and the extent to which farmers succeed in meeting the extra feed requirements for crossbreds. The study reported in this chapter aimed to assess milk production performance of Desi, Gir, Kankrej, Holstein Friesian crossbred and Jersey crossbred cattle in relation to feeding practices in different farm systems of Gujarat, India.

Materials and methods

The study area

The study area was in the state of Gujarat. Gujarat is situated on the West coast of India, covering 196,000 km^2, between 20.1 and 24.4 °N latitude. The state has 50% of its area under cultivation, 10% is under forest, 4% is grazing land, and 23% is waste land (Ghosh, 1991). Rainfed crop production occupies most of the 9.67 million ha of cultivable land, although 23% is already used for irrigated crop production. Average annual rainfall varies from 300 mm in the North West arid zone to 1500 mm in the South, with monsoon rains from mid-June to September. Winter (dry, relatively cold) extends from October to February, summer (hot and dry) is from March to June. Mean daily temperatures vary from 15 °C (January) to 42 °C (May).

For this study we selected 5 agro-climatic zones (Zones 1, 2, 3, 6, and 7) out of a total of 8 zones in the Gujarat Plains and Hills Region (Ghosh, 1991). Table 1 gives some characteristics of these zones.

Table 1. Characteristics of the five Gujarat agro-ecological zones included in this study (after Ghosh, 1991).

Zone	1	2	3	6	7
Physiography	Plain-hilly	Undulating	Plain-hilly	Plain-hilly	Plain-hilly
Soils types	Deep medium light, coastal alluvial	Black loam	Sandy, light black	Shallow, medium light black	Black
depth (cm)	>100	50-100	>100	50-100	50-100
Rainfall (mm)	1000-1500	1000-1200	700-1000	625-750	625-750
Temp. range (°C)	15-40	15-40	15-42	15-42	18-40
Cropping system					
rainfed	+	+	++	++	++
irrigated	++	++	-	-	+

++ major cropping system; + secondary cropping system; - hardly present.

Cattle management

Livestock farmers keep 3 to 8 animals, predominantly cattle (65%), followed by buffaloes, goats and sheep. Livestock are fed a basic diet of straw. Herds are routinely grazed on government and village common lands. Some farmers cultivate forages to supplement milking and working animals. In tribal areas farmers collect weeds and tree leaves to feed the milking and working animals. Animals are generally housed in mud sheds in the backyards of living quarters.

Farmers obtained crossbred cattle via AI with semen from HF and Jersey bulls. Thereafter, crossbred bulls were used to maintain the exotic blood level at 50% to prevent problems of adaptation, as experienced in animals with higher exotic blood levels (Katpatal, 1977; Cunningham and Syrstad, 1987).

Data collection

The field recording covered a period of four years. It began in 1988 at six BAIF dairy cattle production centres, i.e., centres with an extension officer supplying breeding and other services to the farmers in a 10–15 km radius. The number of centres was subsequently increased to 24. The monitoring covered 1331 cow records, representing all breeds, such as Desi, Gir, Kankrej, Holstein Friesian (HF) crosses, and Jersey (J) crosses. The average weights vary from around 325 kg for local Desi animals to 350 kg for Gir, Kankrej and J crosses, and 375 kg for HF crosses.

Data collected included:

- milk offtake (morning and evening) for each cow, every 14 days;
- type and quantity of fresh feeds consumed for each cow (feeds offered minus feed refusals), every 14 days;
- breeding information (e.g., pregnancy diagnosis, calving; mainly to help farmers in breeding management);
- disease problems and mortality;
- grazing period in hours for the community herd;
- family background: tribal or non-tribal.

Feeding practices

The feeds offered were subdivided into three categories: dry feeds, green feeds, and concentrates. The dry feeds fed were mostly sorghum, millet, paddy and maize straws, and dry grass. The green feeds were weeds, forest grass, tree leaves, and cultivated forages such as napier, lucerne, and maize. Concentrates were a mix of compound feeds, brans, damaged grains, and chuni (broken pulses with kernels). The year was divided into two seasons: monsoon season (July to January) with relatively ample grass and other green feeds available, and dry season (January to July) with minimum grazing available.

The estimated composition of feeds was

- concentrates: 90% DM (dry matter), 18% CP (crude protein) and 65% TDN (total digestible nutrients) on DM basis;
- green feeds: 26% DM, 9% CP, 55% TDN;
- dry forages: 85% DM, 4% CP, 50% TDN.

Grazing intake during the monsoon season was estimated to be 2.5 kg d^{-1} DM per cow and CP and TDN as for green feeds (Patil *et al.*, 1993). Grazing intake during the dry season was estimated to be negligible. Maintenance requirements of a cow for energy and protein were estimated to be 30 g TDN and 5 g CP per unit metabolic body weight. The requirements for milk production were assumed to be 350 g TDN and 87 g CP per kg. Nutrient balances were calculated for the different breeds in the two seasons. Total milk production was defined as the milk offtake by the farmer plus the milk intake by the calf. Milk intake by the calf was estimated to be around one third of the milk offtake, as calves are allowed to suckle one teat.

Data analyses

Least squares methods (Harvey, 1977) were used to analyse the variation in daily milk offtake. The analytical model included the effect of social group, agro-climatic zone, breed, calving season, year, parity, interaction breed × social group, the co-variables amount of green feeds, dry feeds, concentrates, and the interactions breed x amount of concentrates and social group × amount of concentrates.

Results

Table 2 gives the average amount of daily DM intake (excluding grazing) for the five breeds. The HF crossbred and J crossbred cows consumed significantly (P<0.01) more DM than the Desi, Gir and Kankrej cows. The amount of dry feeds was significantly higher (P<0.01) for crossbred cows than for local cows. HF cross and J cross cows consumed also significantly (P<0.01) more concentrates than the Desi, Gir and Kankrej cows. Desi cows were offered the lowest (P<0.01) amount of concentrates. Desi and Gir cows consumed significantly (P<0.01) less green feeds compared with HF cross, J cross and Kankrej cows. On non-tribal farms cows were fed, on average, 8.1 kg d^{-1} DM (66% dry feeds, 13% green feeds and 21% concentrates), whereas on tribal farms cows were fed, on average, 6.8 kg d^{-1} DM (54% dry feeds, 24% green feeds and 22% concentrates).

Average milk offtake for the two seasons was the same: 5.2 kg d^{-1} per cow. On average, DM intake was 7.5 kg d^{-1} per cow (52% dry feeds, 27% green feeds and 21% concentrates) in the monsoon season and 7.0 kg d^{-1} (67% dry feeds, 11% green feeds and 22% concentrates) in the dry season. The daily grazing hours were 4–8 h in the monsoon season and 4–6 h in the dry season. In the dry season there is hardly anything

Table 2. Dry matter (DM kg d^{-1}) intake per lactating cow for different breeds in Gujarat.

Breed		Total DM		Dry feeds		Green feeds		Concentrates	
	n	Mean	s.e.[1]	Mean	s.e.	Mean	s.e.	Mean	s.e.
Desi	648	6.6^{a}	0.19	4.2^{a}	0.18	1.3^{a}	0.04	1.1^{a}	0.04
Gir	202	7.4^{a}	0.30	4.4^{a}	0.28	1.4^{a}	0.06	1.6^{b}	0.05
Kankrej	210	7.2^{a}	0.32	3.8^{a}	0.30	1.7^{b}	0.06	1.7^{b}	0.05
HF cross	181	9.5^{b}	0.32	5.8^{b}	0.30	1.7^{b}	0.07	2.1^{bc}	0.05
J cross	90	9.0^{b}	0.44	5.2^{b}	0.41	1.7^{b}	0.09	2.1^{bc}	0.08

Means with different subscripts are significantly different at P<0.01;

[1] s.e.: standard error.

to graze. So, only for the monsoon season 2.5 kg d^{-1} DM per animal was added to the amount of feed fed to provide the nutrient balances. Figure 1 shows the TDN and CP balance as a percentage of the requirements for the different breeds in the two seasons. Protein was a limiting nutrient in both seasons and in all breeds. Figure 1 shows that there was also an energy shortage in the dry season. The nutrient balances were more negative for J cross cows than for cows of the other breeds.

Table 3 gives the corrected means and standard errors for milk offtake. Cows of non-tribal farmers produced significantly more milk than cows from tribal farmers (P<0.001). The performance of HF and J crossbred cows did not differ between tribals

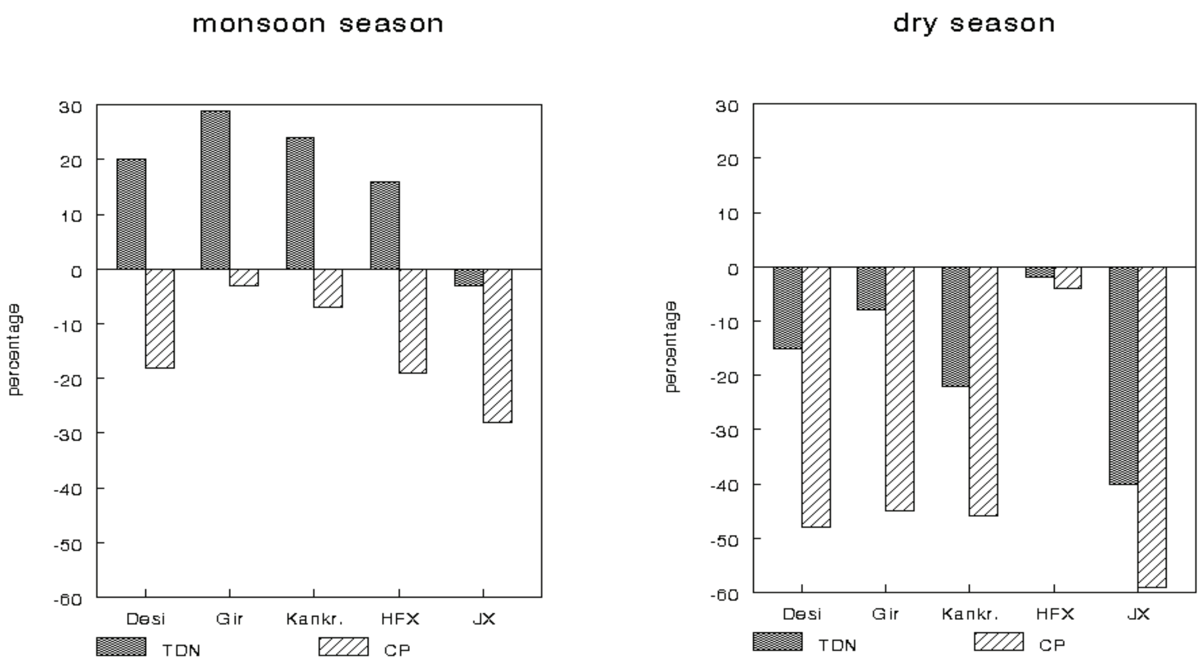

Figure 1. TDN and CP balances as a percentage of the requirements for a lactating Desi, Gir, Kankrej (Kj), HF cross (HFX), and J cross (JX) cow in the monsoon and dry season in Gujarat.

and non-tribals, but the Indian breeds produced better on non-tribal farms. Overall the differences in milk offtake between zones were small. Zone 7 had significantly ($P<0.001$) lower milk offtake than the other zones. The effect of parity on production shows that milk yield gradually increased from the first to the fourth lactation. The year effect shows that the calving year of 1989 had significantly higher production than 1988 and 1990 ($P<0.001$). The regression coefficients for green feeds and dry forages indicate that these feeds had a small negative ($P<0.001$) effect on milk production. An increase of 1 kg of concentrates gave an increase of 1.28 kg in milk offtake in HF crossbreds. This regression coefficient was significantly different ($P<0.001$) from the regression coefficients for the other breeds. In Desi, Gir, Kankrej and J cross cows the milk offtake increased by only 0.84, 0.58, 0.54, and 0.56 kg, respectively. On non-tribal farms cows responded more ($P<0.001$) to feeding concentrates than on tribal farms. The coefficient of determination for the model used was 54%. The breed and the amount of concentrates fed contributed most to the variation in daily milk offtake.

The lactation periods for Desi, Gir, Kankrej, HF cross, and J cross cows were 254, 246, 236, 264, and 264 d, respectively. The intercalving period could be estimated in only 108 cows. For Desi, Gir, Kankrej, HF crosses, and J crosses the intercalving periods were 540, 556, 534, 488, and 485 days, respectively. During the monitoring period no systematic health problems occurred and only very few deaths (5 animals) were recorded.

Discussion

The differences in agro-climatic characteristics between zones were not reflected in differences in milk offtake. Zone 7 is located near the coast. In this area the milk marketing infrastructure is poor. The Gir breed originated in this area. Gir breeders are more interested in selling of breeding stock than in a high milk offtake. The likely reason that the milk offtake was significantly lower in zone 7 than in the other zones (Table 3), is that farmers prefer to give their calves a bigger share of the milk than in the other zones. So, our estimate that the milk intake by the calves was one-third of the milk offtake was questionable for zone 7. Our findings agree with the conclusion of De Boer *et al.* (1994a) that for livestock, the use of agro-climatic macro-regions to target development activities can be questioned. Feed availability at farm level, marketing infrastructure, and socio-economic parameters are some of the additional factors to be considered.

The lower milk offtake of cows of tribal farmers compared to cows of non-tribal farmers was caused by the low milk offtake of indigenous cows on tribal farms. This may be due to the management and genetic background of local animals in the areas where tribals live. In the non-tribal areas, one finds traditional breeding practices and

Table 3. Least squares means and regression coefficients for various factors with milk offtake (kg) per lactation day as the dependent variable.

Variable		n	l.s. mean	s.e.[1]	l.s. mean	s.e.	regression	s.e.
Overall average		1331	4.60	0.16				
Social group								
non-tribals		478	5.00^{a}	0.20				
tribals		853	4.21^{b}	0.19				
Agro-ecological zone								
1		133	4.79^{a}	0.25				
2		478	4.98^{a}	0.20				
3		427	4.75^{a}	0.17				
6		222	4.63^{a}	0.20				
7		71	3.89^{b}	0.31				
Social group × breed								
non-tribals	Desi	179	4.03^{a}	0.21				
	Gir	160	4.64^{b}	0.22				
	Kankrej	59	3.96^{a}	0.26				
	HF cross	52	6.63^{c}	0.31				
	J cross	28	5.73^{df}	0.35				
tribals	Desi	469	3.16^{e}	0.19				
	Gir	42	2.78^{e}	0.29				
	Kankrej	151	2.78^{e}	0.23				
	HF cross	129	6.46^{cdf}	0.24				
	J cross	62	5.88^{cdf}	0.27				
Lactation								
1		303	4.24^{a}	0.11				
2		516	4.54^{ab}	0.10				
3		323	4.67^{b}	0.12				
4		125	4.89^{b}	0.16				
5		39	4.35^{ab}	0.26				
6		25	4.81^{ab}	0.40				
Calving year								
1988		176	4.26^{a}	0.22				
1989		457	4.94^{b}	0.18				
1990		562	4.62^{ac}	0.16				
1991		136	4.60^{abc}	0.21				

Table 3. Continued.

Variable		n	l.s. mean	s.e.	l.s. mean	s.e.	regression	s.e.
Season								
monsoon		598	4.62[a]	0.17				
dry		733	4.59[a]	0.17				
Dry feeds	(kg d^{-1})						–0.05***	0.01
Green feeds	(kg d^{-1})						–0.05***	0.02
Concentrates	(kg d^{-1})						0.76***	0.07
Breed × concentrates								
Desi							0.84***[a]	0.08
Gir							0.58***[a]	0.13
Kankrej							0.54***[a]	0.18
HF cross							1.28***[b]	0.14
J cross							0.56***[a]	0.12
Social group × concentrates								
non-tribals							0.96***[a]	0.10
tribals							0.56***[b]	0.08
R^2 full model[2]: 54%								

l.s. means with different superscripts are significantly different at P<0.001;

*** significance regression coefficients P<0.001;

[1] standard error;

[2] coefficient of determination.

specific breeders for Gir and Kankrej cattle. In the tribal areas, most local animals are so-called ‘nondescript’ Desi and they tend to be smaller than in non-tribal areas.

Crossbred cows were fed 1.4 times more concentrates, and about 1.2 times more green and dry feeds than the local cows. The higher amounts of feed fed to crossbreds compared to the other animals illustrates that the farmers with crossbred cows try to adjust their feeding of concentrates according to the needs of the animals. We could only give a general estimate for the DM intake via grazing. Also the nutrient balances do not consider differences between zones in grazing availability. So, our feed balance estimates are only rough approximations. Still, the results (Figure 1) indicate that there are TDN and CP deficiencies in the dry season. In all breed groups, except the HF crossbreds, the CP deficiency is substantial. CP also is deficient in the monsoon season.

Average milk offtake was about the same in both seasons, although the nutrient balances indicate a severe protein and energy shortage in the dry season. One reason why milk yields were not higher in the monsoon season, may have been that farmers are mainly occupied with crop activities. Changes in body weights could not be monitored, but, it is well known that lactating cows loose weight in the dry season. In the monsoon season, cows can recover some of their weight loss from the dry season. However, most of the weight gain will occur in the 7.5–10 month period between two lactations.

In reality, the dry period will be even longer because the estimates of intercalving periods are based solely on cows with two consecutive calvings during the monitoring period. Thus, these estimates will be too optimistic, because cows with only one calving or no calving in the monitoring period are not included. Nevertheless, the 2 months shorter intercalving periods of crossbred cows compared to cows of the Indian breeds are in accordance with the experiences of the farmers that locally born crossbreds (the great majority of the crossbreds in this study) show less fertility problems than cows of the Indian breeds or crossbred cows imported from other states.

The feed deficiencies can be corrected by adjusting the feeding practices. Feeding additional concentrates, such as bran plus urea, can compensate for both the TDN and CP deficiencies in all breeds, except the J crosses. This is more feasible for non-tribal farmers, because of their higher farm incomes. Urea treatment of straws can help to correct the CP deficiencies, particularly in the monsoon season and in zones where high amounts of straws are fed. The CP deficiencies in the dry season are too high to be corrected by straw treatment. Straw treatment is not economically feasible for cows with low milk yields (Schiere and Nell, 1993). One option for tribal farmers could be leguminous tree leaves, because, in general, tribal farmers have excess labour and therefore the labour-intensive practice of planting trees and collecting leaves every day is not an obstacle for them.

Both social groups are interested in using crossbreds as dairy animals. And crossbred cows perform equally well on tribal and non-tribal farms. In Gujarat the total number of crossbreds has increased from 1% to 7% of the total cattle population in the period 1982–1992 (Anonymous, 1993). Our results indicate why farmers are interested in obtaining crossbred cows. Farmers prefer HF crosses over Jersey crosses, because of their higher milk yields. The very negative feed balance estimates for Jersey crosses also indicate that these animals are less appreciated. More research is needed into changes in herd composition and allocation of feed resources to other types of animals resulting from keeping crossbred cows. Added to this, the socio-cultural implications need to be studied, e.g., the increase in labour for women as they do the majority of the cattle management chores.

Disadvantages of crossbreeding programmes are the risk of the loss of local genetic resources and the reduction in hybrid vigour in the later generations of crossbreds. Since 1994, BAIF supplies Gir semen to Gir breeders to try to maintain the quality of the Gir breed. Syrstad (1989) reviewed dairy cattle crossbreeding in the tropics. He concluded that milk production was, on average, 24% lower in the F_2 than in the F_1. The great majority of the crossbreds in this study were F_1 animals. As yet, no field data are available on production performances of F_2 crossbred cattle. Monitoring the performances of F_2 crossbreds is strongly recommended.

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CHAPTER 4

The impact of crossbred cows at farm level in mixed farming systems in Gujarat, India*

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Summary

This study aimed to quantify the impact of crossbreeding at farm level, in mixed farm systems in Gujarat. Households with crossbred cattle did not differ from households without crossbreds in terms of farm resources, crop gross margins and off-farm income. The use of crossbred animals did increase livestock gross margins by 64%, and household income by 22%. The three agro-ecological zones included in this study differed considerably according to farm system and household income. However, in all three zones, households with crossbreds had higher livestock gross margins than households without crossbreds. There was no real difference in work load and labour division between households with and without crossbreds. There was also no difference in the use of bullocks for draught purposes between the two types of households. In particular buffaloes are being replaced by crossbred cattle. There was a large variation in farm income, largely because of land area. The milk offtake per average cow and the number of buffaloes also related positively to farm income in both types of households. Crossbreeding has proved technically and financially viable in different Gujarat mixed farming systems. It can be concluded that crossbreeding is an important development option for landless farmers.

Keywords: Cattle, Crossbreeding, Farming Systems, Economics, India.

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Introduction

Rural areas in Gujarat are characterized by subsistence-oriented, smallholder farms. Whereas, in the past, nomadic herders used to travel with their herds and flocks, using local crop residues and then returning manure to the crop farmers, livestock are now an integral part of mixed farms. In Gujarat, as in the whole of India, the interest in cross-breeding is increasing and the introduction of Holstein Friesian and Jersey crossbreds is emerging as a major activity in development programmes (Patil and Udo, 1997a). Each farmer who requests crossbred cattle is supplied with semen from Holstein Friesian or Jersey bulls to inseminate his cows, irrespective of the specific conditions in the various farming systems. Continued population pressure will entail continued decrease in farm sizes. The introduction of crossbred cows could be a suitable development option for farm households with little or no land, provided that these households have access to sufficient feed sources.

A previous paper (Patil and Udo, 1997a) evaluated milk offtake and feeding practices at the animal level. Crossbreds produced, on average, 1.8 times more milk than local Desi, Gir, and Kankrej cows. They were fed 1.4 times more concentrates, and 1.2 times more green and dry feeds than local cows.

The use of crossbred cattle in Indian farming systems is currently being debated, due to some undesirable consequences, such as the extra costs for feed and veterinary treatments, the capability of crossbred bullocks for draught purposes, the expected increase in labour for women, and doubts about whether such cattle fit into all existing mixed farming systems (Jackson, 1982; McDowell, 1983; Rao *et al.*, 1995). Thus, added to the evaluation of crossbreeding at an animal level, a systems approach is needed to evaluate the consequences of crossbreeding at the farm level.

We studied existing mixed farms with and without crossbred cattle, and quantified some of the economic components, to evaluate the impact of crossbreeding at farm level in Gujarat, India.

Materials and methods

The study area

The Gujarat area has already been described by Patil and Udo (1997a). The state can be divided into different agro-climatic zones, on the basis of its climate and soil types, for planning location-specific research and development programmes (Ghosh, 1991). About one-sixth of the farming households belong to the socio-economically less-favoured tribal groups.

For this study we selected three zones (Zone numbers 1, 3, and 6) out of the eight zones of the Gujarat Plains and Hills Region (Ghosh, 1991). Table 1 gives some of the characteristics of these three zones. Mixed farming with rainfed crop production is predominant, although the use of irrigation is increasing, in particular in Zone 1.

Cattle management

Livestock farmers keep mainly cattle and buffaloes. Cattle breeds are Desi, Gir, Kankrej, Holstein Friesian crosses and Jersey crosses. In crossbred animals the exotic blood level is maintained at 50%. Buffaloes belong to the Surati, Mehsani and Jafrabadi breeds or are so-called non-descript. Livestock are fed crop by-products (sorghum, millet, paddy and maize straws), green feeds (weeds, forest grass, tree leaves and cultivated forages), and concentrates (brans, damaged grains and broken pulses with kernels). Herds are routinely grazed on government and village common lands. Animals are generally housed in mud sheds in the backyards of living quarters. Cattle management is described in detail by Patil and Udo (1997a).

Data collection

Agricultural activities and off-farm activities were monitored in 15 villages during the period June 1993 – May 1994. The stratification of farmers as tribals and non-tribals was based on family information. In total, 311 households were randomly selected (9% of the total households, with a minimum of 20 households per village), representing both social groups proportionately in each village. Data were collected on the family structure, assets, livestock, land area, land use, and labour in June 1993. Detailed

Table 1. Characteristics of the five Gujarat agro-ecological zones included in this study (after Ghosh, 1991).

Zone	1	3	6
Physiography	Plain-hilly	Plain-hilly	Plain-hilly
Soils types	Deep, medium light, coastal alluvial	Sandy, light black	Shallow, medium light black
depth (cm)	>100	>100	50-100
Rainfall (mm)	1000-1500	700-1000	625-750
Temp. range (°C)	15-40	15-42	15-42
Cropping system			
rainfed	+	++	++
irrigated	++	-	-
Crops	paddy, sugarcane, fruits	paddy, millet, pulses, sorghum	groundnut, cotton, sorghum, wheat

++: major cropping system; + : secondary cropping system; - : hardly present.

recording of all inputs and outputs of crop and livestock was done regularly every week during the cropping and harvesting season (June to October) and fortnightly in the other months until June 1994.

Procedures and assumptions in the economic evaluation:

- inputs to the livestock sub-system were crop by-products (such as straw, husks, weeds, brans, damaged grains), labour, concentrates, treatment costs, and buying of animals;
- output from the livestock sub-system were milk, draught, manure, and sale of animals;
- inputs to the crop sub-system were seeds, fertilizers, pesticides, draught, manure, hired labour, and threshing costs;
- outputs from the crop sub-system were food grains (maize, rice, millet, pulses), cash crops (cotton and vegetables), and straw, husks, weeds and brans for livestock;
- actual farmgate prices were used for accounting in Rupees (Rs);
- household consumption was expressed in farmgate prices;
- draught and manure opportunity costs were based on market rates;
- gross margins of the two sub-systems were calculated on the basis of output minus cash inputs including hired labour;
- farm income was calculated as the gross margins from crops and livestock;
- household income was calculated as farm income plus off-farm income.

Farm income combined two main functions of agricultural activities: the supply of food for home consumption, and generation of a cash income. We used least squares methods to explain the variation in farm income in terms of differences in farm resources. The analytical model included the effects of zone and social group, and the co-variables were land area, cropping intensity, labour force, number of cattle, number of buffaloes, number of bullocks, milk offtake for the average cow, cash input per unit crop land, and cash input per livestock unit. The above-mentioned co-variables were calculated as follows:

- land area; land holding per farm in ha;
- cropping intensity; average percentage cropped of the agricultural area;
- labour; labour force employed for crops and livestock, including family labour as well as hired labour, in full-time equivalent of 7 h d^{-1};
- number of cattle, buffaloes or bullocks; number of these types of animals per farm;
- average milk offtake; average milk offtake per animal (lactating and dry cows, including buffaloes) in kg per year;
- cash input per animal was calculated as the amount spent annually per adult animal on concentrates, treatments, and hired labour;
- cash inputs per ha; amount spent annually on seed, pesticides, fertilizers, hired labour, hired bullocks, manure, and irrigation.

Results

Table 2 shows the means and coefficients of variation for farm resources, crop and livestock gross margins, off-farm income, and household income for households with or without crossbred cattle, subdivided in landless households and households with land. Average family size was 6.0 in households with crossbreds and 6.5 in households without crossbreds. Average farm size, labour employed per year, cropping intensity, the use of bullocks, and the number of large ruminants, were about the same in households with and without crossbreds. Herd composition differed between these two types of households. In households with crossbreds, buffaloes made up 14% of the herd, in households without crossbreds this was 30%. Milk offtake per average cow was about 1.7 times higher in households with crossbreds than in households without crossbreds. In households with crossbreds cash inputs per unit of land and per animal were higher than in households without crossbreds. Household income was 22% higher in households with crossbreds than in households without crossbreds. This difference was almost completely due to the higher livestock gross margins in households with crossbreds: Rs 12,000 *vs* Rs 7,300 for households without crossbreds. Crop gross margins and off-farm income were about the same in both types of households. Only, off-farm income was higher for landless farmers with crossbreds than for landless farmers without crossbreds.

In households with crossbreds and with land, 55% of the labour employed was used for livestock-related activities, and livestock contributed 54% to farm income. In households without crossbreds and with land, 59% of the labour was used for livestock, yet, livestock only contributed 41% to farm income. Women contributed 123 d y^{-1} and 108 d y^{-1} to livestock-related activities in households with and without crossbreds, respectively. In crop-related activities more hired labour was used than in livestock related activities. Both men and women labour was hired for crop-related activities, whereas for livestock-related activities (mainly herding) only men were hired.

The number of large ruminants kept by landless households was, on average, only 40% of the number of large ruminants kept by households with land. In landless households without crossbred cattle, buffaloes are the most important large ruminant. Landless households that have changed over to crossbreds have replaced almost all their buffaloes by crossbreds. The off-farm income for landless households was considerably higher than for households with land, in particular for the group with crossbred cattle. The landless farmers with crossbreds had relatively high livestock gross margins per animal: Rs 3,500 per animal *vs* Rs 2,200 per animal for households with land and crossbreds. For landless households with local cattle the average livestock gross margins per animal was Rs 1,800 and for households with land this figure was Rs 1,400.

Figure 1 shows that the three agro-climatic zones differ in land area and herd size.

Table 2. Selected variables, Gross Margins, and Off-farm and Household Income for mixed farm households with or without crossbred cattle, subdivided in landless households and households with land in Gujarat, India.

	With crossbreds						Without crossbreds					
	landless		with land		all		landless		with land		all	
	x	cv	x	cv	x	cv	x	cv	x	cv	x	cv
Number of households	40		114		154		37		120		157	
Number of household members	5.1	36	6.3	36	6	37	5.2	36	6.9	47	6.5	48
Labour employed (d y^{-1})												
in crops			206	94					177	76	-	
women (%)			37						41			
hired labour (%)			33						25			
in livestock	223	58	248	60	242	58	230	60	258	50	252	52
women (%)	60		48		51		49		42		43	
hired labour (%)	0		15		11		14		17		16	
Land size (ha)			1.5	87			-		1.7	85	-	
Cropping intensity (%)		-	120	38					125	35	-	
Bullock pair used (d y^{-1})	-		21.4	99	-				21.2	109	-	
Number of large ruminants	2.6	57	5.8	54	5	62	2.5	62	5.9	61	5.1	68
cows plus calves (%)	94		65		69		39		48		48	
buffaloes plus calves (%)	4		15		14		55		26		30	
bullocks (%)	2		20		17	17	6		25		22	
Milk offtake per average cow (kg)	1398	72	1298	81	1324	78	632	105	812	110	771	111
Cash inputs (Rs × 1000)												
per ha	-		4.8	78	-		-		3.9	81	-	
per livestock unit	0.9	102	0.7	104	0.7	105	0.5	137	0.5	113	0.5	119
Crop Gross Margins (Rs × 1000)	-		10.9	187	8.1	226	-		11.9	186	9.1	221
Livestock GM (Rs × 1000)	9.0	76	13.0	166	12.0	159	4.5	113	8.4	123	7.3	130
Off-farm Income (Rs × 1000)	9.7	150	4.3	170	5.7	174	6.1	124	4.2	186	4.5	170
Household income (Rs × 1000)	18.6	89	28.3	105	25.9	106	10.6	102	24.5	111	20.9	121

[1] coefficient of variation (%); Rs: Rupees (1 US$ = 30 Rs).

However, the differences in farm and herd sizes between farms with and without crossbreds are small. In all three agro-climatic zones, in farms with crossbreds the number of cattle is increased at the expense of the number of buffaloes.

Figure 2 gives the crop gross margins, livestock gross margins, and off-farm income for the three zones and farms with and without crossbreds. In all three zones the livestock gross margins in farm households with crossbreds were higher than in households without crossbreds. In Zones 1 and 6 households with crossbreds showed lower crop gross margins than households without crossbreds. In Zone 3, it is the other way around. Zone 3 has hardly any possibilities for off-farm income. In Zone 1 extensive use of irrigation is made. In Zone 6, farms are larger than in the other two zones and farms without crossbreds have, on average, more land than farms with crossbreds.

Table 3 shows the amounts of crop by-products produced, and the amounts of concentrates, green feeds and crop by-products fed per farm per year. Grazing intake is not included in this table. As could be expected, on farms with crossbred cattle more feed was offered to the animals. On farms without crossbreds not all crop by-products produced were used to feed the cattle. The green feeds (roadsides, communal lands, weeds) are cut-and-carried to the animals. Landless farmers have to buy some of the crop by-products or are allowed to take some crop by-products home when some of their household members are working as labourers in harvesting crops.

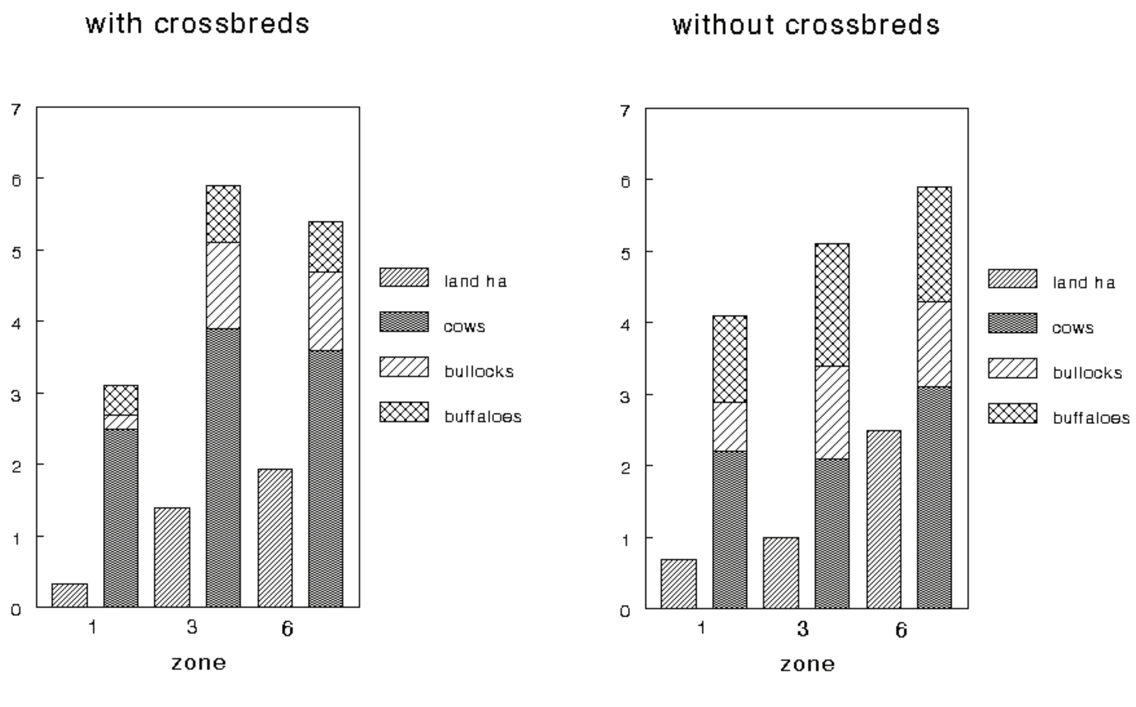

Figure 1. Land area and herd sizes for farms with or without crossbreds in three agro-ecological zones in Gujarat, India.

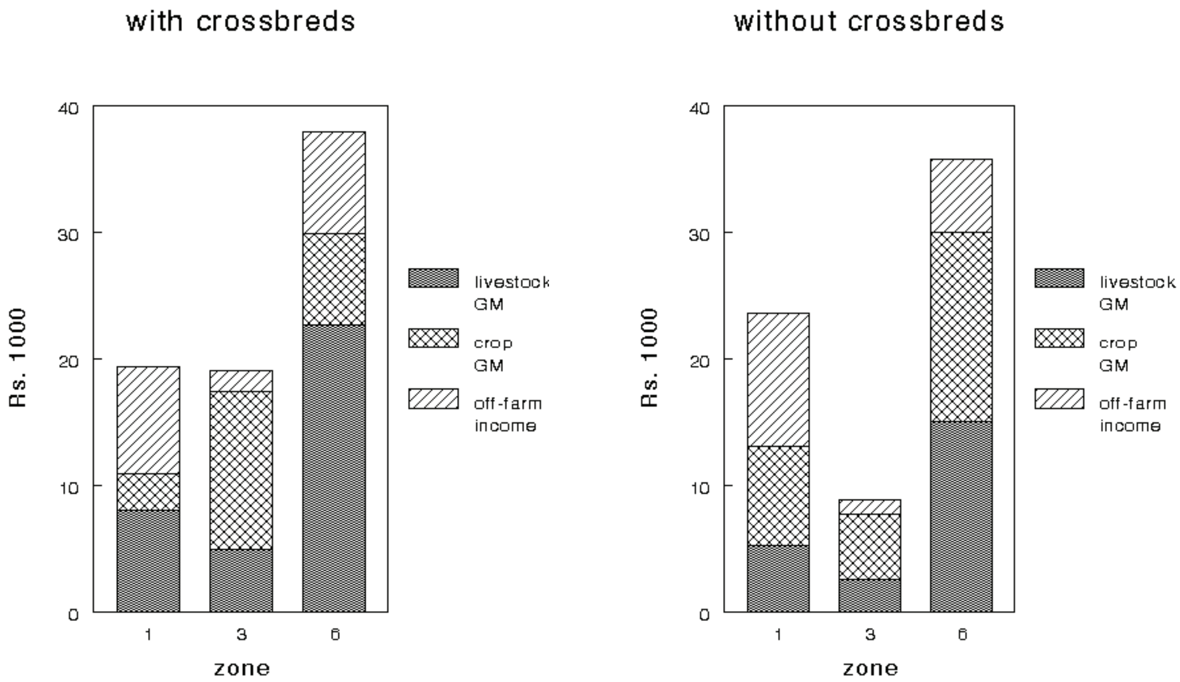

Figure 2. Livestock Gross Margins, Crop Gross Margins and Off-farm Income for farms with or without crossbreds in three agro-ecological zones in Gujarat, India.

Table 3. Amounts of crop by-products produced, and concentrates, green feeds and crop by-products fed per farm per year (excluding grazing) for mixed farm households with or without crossbred cattle, subdivided in landless households and households with land in Gujarat, India.

	With crossbreds		Without crossbreds	
	landless	with land	landless	with land
Produced (kg y^{-1})				
crop by-products	-	3193	-	3124
Fed (kg y^{-1})				
concentrates	558	639	133	439
greens	5140	4113	2123	4042
crop by-products	1853	2621	1086	2113
Number of large ruminants	2.6	5.8	2.5	5.9

The very large coefficients of variation in most of the variables presented in Table 2 indicate that the two groups are not very homogeneous for the variables selected. In Table 4 the variations in farm income are analysed by least squares methods. In households with crossbreds the analytical model contributed 66% to the total variation in farm income. Tribal households with crossbreds had a significantly ($P<0.05$) higher

Table 4. Least Squares means and regression coefficients for various farm resources with annual Farm Income (in Rs) as dependent variable for mixed farm households with or without crossbred cattle in Gujarat, India.

	With crossbreds		Without crossbreds	
	l.s. mean[3]	s.e.[1]	l.s. mean	s.e.
Overall average	20,926	1,381	17,711	1,339
Zones				
1	19,480	2,967	27,063[a]	3,539
3	19,650	2,635	13,346[b]	2,172
6	23,647	3,391	12,724[b]	2,979
Social group				
tribals	25,076[a]	2,543	13,656[a]	2,215
non-tribals	16,776[b]	1,981	21,765[b]	1,905
	Regression[4]		Regression	
land area (ha)	7,404***	1,340	11,169***	1,191
cropping intensity (%)	–65	39	–91**	31
labour force (d y^{-1})	27***	7	5	8
number of cattle	2,918**	942	330	790
number of buffaloes	6,612***	1,048	1,352*	683
number of bullocks	–461**	143	2	106
milk off-take per cow (kg)	9***	1	5*	2
cash input per LU (Rs)	–3	2	–5	3
cash input per ha (Rs)	1	1	1	1
R^2 full model[2] (%)	66		65	

[1] standard error; [2] coefficient of determination;

[3] l.s. means with different subscripts are significantly different, P<0.05;

[4] significance regression coefficients: * P<0.05; ** P<0.01; *** P<0.001.

farm income than non-tribals with crossbreds. The magnitude of the regression coefficients indicates the extent to which specific farm resources increase or decrease farm income. Land area, labour force, number of buffaloes, and average milk offtake per cow had very significant (P<0.001) positive effects on farm income. The number of cattle also related significantly (P<0.01) positively to farm income. The number of bullocks had a significant (P<0.01) negative effect on farm income. In households without crossbreds, the analytical model explained 65% of the variation in farm income.

The adjusted means for the three zones indicate that Zone 1 (with extensive use of irrigation) had a significantly ($P<0.05$) higher farm income. Non-tribals had a significantly ($P<0.05$) higher farm income than tribals. Land area had a very significant ($P<0.001$) impact on farm income. Cropping intensity had a negative ($P<0.01$) effect on farm income. The number of buffaloes and the milk offtake per cow had a significant ($P<0.05$) positive effect on farm income. Cash inputs per unit area or per animal did not contribute significantly to farm income.

Discussion

In India, milk and milk products are traditional components of the human diet. There also is a relatively well developed marketing infrastructure. Consequently, crossbreeding with dairy type animals is a livestock intervention that could prove relatively more successful than in countries where milk is not a traditional commodity. This study shows that the higher milk offtakes and lower feed costs per kg of milk of individual crossbred animals (Patil and Udo, 1997a) can be extrapolated to the farm level. Farms with crossbreds had 64% higher livestock gross margins and 22% higher household income than farms without crossbreds. In studies where there are differences in technical or economic parameters between adopters and non-adopters it can always be queried what is cause and what is effect. Labour use, land size, land use, use of bullocks, number of large ruminants, and the crop gross margins and off-farm incomes were not much different between the two types of households. So, it can safely be concluded that the higher household income of farms with crossbreds is due to the use of crossbred cows.

Indian rural women consider livestock as their traditional responsibility (Rangnekar *et al.*, 1993b). Livestock interventions that require more work of the women are likely not to be accepted (Dieckmann, 1994). It was thought that crossbreeding would be an intervention that increases the work load for women, however, our results do not show any great differences in work load and labour division between households with and without crossbreds. On farms without crossbreds and with land, livestock is relatively more labour-intensive than crop production; livestock contributes 41% to farm income, but takes 59% of the farm labour.

The three agro-ecological zones included in this study considerably differed in farm size and household income. However, in all three zones, households with crossbreds had higher livestock gross margins than households without crossbreds. For two of the three zones it can be speculated that farms with less resources (land size, possibilities for irrigation) for crop production change over to crossbred cattle. In the other zone, with almost no possibilities for off-farm income, it is exactly the opposite. Here, the farmers with relatively more land and higher crop gross margins keep crossbreds.

Initially, farmers had some reservations about the use of crossbreds. They objected to the ‘ugly’ appearance of crossbreds. They greatly value the majestic look of their local breeds Gir and Kankrej. A second reservation against crossbreds was that they were afraid that crossbred bullocks would be less suitable for draught purposes, because their hump is smaller than that of local bullocks. At present, farmers use crossbred bullocks for working, but they have to shift the working hours to the early and later parts of the day to reduce their heat load. Our results indicate that the introduction of crossbred animals has not really reduced the use of bullocks on farms with land, as feared by Jackson (1982) and Rao *et al.* (1995). Bullocks comprise about 20–25% of the herds on these farms, but their use (21 d y^{-1}) is limited to the short cropping season. During the other parts of the year they do not have enough work but have to be fed. This might explain that the number of bullocks had a negative effect on farm income in households with crossbreds.

It is notable that, in particular the number of buffaloes is reduced on farms with crossbred cattle, despite the fact that the number of buffaloes per farm had a positive impact on farm income in both types of households. The milk price for buffalo milk is higher than for cow milk. Some of the households with buffaloes sell ghee. Still, most farmers prefer crossbred cows, because of their higher milk yields.

Land is the major resource of mixed farms. An increase of one ha in land area was estimated to boost farm income by 35% and 63% in households with and without crossbreds, respectively. The number of cattle had a positive effect on farm income in farms with crossbreds. Milk offtake for the average cow had a positive impact on farm income in both types of households. Milk offtake is an indicator of the management of the herd. It combines the milk offtake from lactating cows with the percentage of cows in milk. Landless farmers with crossbreds showed the highest milk offtake for the average cow. Table 3 shows that these households also feed their animals relatively better. So, the introduction of crossbred cows is particularly useful, in terms of livestock gross margins, for landless households (Table 2).

One of the findings of the animal level evaluation of crossbreeding (Patil and Udo, 1997a) was that on tribal farms, local cows produced less milk than on non-tribal farms, whereas crossbreds produced the same amount of milk on both tribal and non-tribal farms. The adjusted means for tribal and non-tribal farm gross margins indicate that in farms without crossbreds the estimated farm income also was far below the value for non-tribal farmers. However, tribal farmers who changed over to crossbred cattle are doing better than non-tribal farmers. So, crossbreeding can be an important development option for tribal areas.

Hence, it can be concluded that crossbreeding can be an important development option for different types of farm systems. The use of crossbreds could imply a reduction in herd size, which might also help in preventing degradation of forest and common grazing lands. Indeed, preliminary data of some 270 herds in Gujarat indicate that in the last five years the average number of cattle and buffaloes has decreased by 13%, whereas the percentage of crossbred cattle in these herds has increased from about 6% to 21%.

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CHAPTER 5

Screening feed technologies for crop-livestock farming: Case studies from Gujarat, India

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Summary

Research in animal nutrition has yielded a variety of 'on-the-shelf technologies' but many of these are not adopted as widely as is often hoped. Modelling approaches can be used to explore where and when certain technologies are useful in farming systems. This allows putting disciplinary approaches like animal breeding and nutrition in a broader context of actual farming. Particularly the limited purchasing power in low input systems forces farmers to derive a livelihood by carefully adjusting the resources and production factors of their farms. The cases of this chapter explore the suitability of animal breeding combined with feeding technologies such as urea supplementation, use of concentrates, gotar (pigeon pea leaves), urea-treated straw with concentrates, and leuceana tree leaves for crop-livestock systems in Gujarat, India. Case I uses simple partial budgeting to test feasibility of feeding concentrates to dairy cows. Case II uses a herd dynamics model to establish how changes in feeding strategy affect different animal production parameters. Case III uses linear programming to study how animal production levels (medium-yielding crossbreds *vs* low-yielding local cows), feeding technologies and cropping patterns combine for an optimal farm income in a mixed crop-livestock system. Case I with partial budgeting illustrated that concentrate feeding was beneficial to farmers having market access and crossbred cows. The multi-criteria simulation of Case II showed that the cross-breeding interventions were more remunerative for landless, and tribal farmers than for non-tribal farmers. And feeding interventions were more effective with crossbreds than with local cows. The linear programming used in Case III indicated that maximum farm income was achieved with medium milk yields per animal (~10 kg^{-1} d^{-1}). Higher milk yields require use of better feeds and they render the straws of the grains useless for feeding. The farm plan would then shift from using combined value of grain and straw into single (but lower) value of cotton. A major message of the three types of modelling in a farming systems context is that they illustrate a shift from a reductionist to a more holistic paradigm.

Introduction

Research in animal nutrition has yielded a variety of 'on the shelf technologies' (Table 1). Many of these, however, have not been adopted as widely as one might have hoped (Owen and Jayasurya, 1989; Röling, 1989; Udo and Cornelissen, 1998). Some caused negative side effects after initial success, e.g., in terms of social change, but this is not unique for animal nutrition. Also agronomists know that new technology is not applicable everywhere and that it can even backfire through negative social and environmental trade-offs (Conway and Barbier, 1990; Collinson, 2000). Low adoption rates and negative trade-offs were major drivers behind the development of Farming System Research (FSR) methodologies in the 1980s and 1990s. Two of the principles underlying FSR is that a technology is only useful in certain places (niches), and that an intervention successful in one place can cause unexpected and undesired effects elsewhere (Conway and Barbier, 1990; Collinson, 2000).

Somehow, indeed, the link between research and practice in agricultural development appears to be broken, resulting in the question of researchers: "*how do I make my (feeding) technology accepted by farmers*". Researchers are often frustrated because farmers seem to have other perceptions, time scales and priorities than anticipated in the research station. Methods developed in the laboratory or in desk studies do not necessarily address issues and values felt by farmers (Schiere, 1993; Chambers, 1997). Farming System Research (FSR) uses a variety of approaches to re-establish the link between theory and practice. One set of these tools comprises a range of modelling approaches. Modelling studies can help to explore the suitability of feeding technologies. To some extent, they may even support 'prediction' of social and biophysical side effects (Shaner *et al.*, 1982). The use of such models can save resources that would otherwise be needed to rather 'arbitrarily' test the suitability of technologies in the field. Models can also help to set future research priorities by supporting discussions and observations in the field (Udo *et al.*, 2006). As an illustration of the capabilities of the set of modelling tools, this chapter uses three distinct modelling approaches to screen feeding technologies for crop-livestock farming systems in Gujarat, India. The first is rather straightforward partial budgeting to examine the usefulness of concentrate feeding in dairying, using only marginal cost/benefit analysis. The second looks at effects of different feeding methods on individual cow and herd performances. The third uses linear programming to consider the combined effect of feeding technology and animal (= breed) performance and cropping patterns on total farm income.

Feeding technologies

Many technologies have been developed for the improvement of ruminant nutrition based on the use of crop residues in smallholder farming systems. Table 1 gives an overview of feed technologies tested in an Indian-Dutch research and development program (Schiere *et al*., 2000). Some of these technologies aim at better combining or utilizing available resources at rumen level, e.g., supplementation with critical nutrients (Preston and Leng, 1987), others at extracting more from existing resources by chemically treating crop residues (Sundstol and Owen, 1984; Kiran Singh and Schiere, 1995), while production and conservation of fodder has also been well-researched (Bogdan, 1997; Skerman, 1977). Other technologies, such as modified

Table 1. Major categories of *on-the-shelf* technologies tested for ruminant feeding in crop-livestock farming in India (Sources: Ranjan, 1981; Relwani, 1983; Preston and Leng, 1987; Schiere and Ibrahim, 1989; Patil *et al.*, 1993; Prasad *et al.*, 1993; Sampath *et al*., 1993; Joshi *et al.*, 1995; Kiran Singh and Schiere, 1995; Sharma *et al*., 1995; De Jong, 1997).

Catogory	Interventions[2]	Effects
Supplementation		
Catalytical, substitutional; strategic	• Urea-treated rice bran and gotar[1] (1)	Use of local feed re-sources, by slighting increasing digestibility and intake
	• rice bran and leuceana leaf meal	
	• Various levels of concentrate: A low; B medium; C high (3)	Increases protein and energy content
	• Urea-treated straw combined with low (A) and medium (B) levels of concentrate (4)	Increase straw intake, digestibility and protein content
Crop residue feeding		
Untreated; treated with chemical/biological and/or physical means; chopping; soaking	• Urea treatment of straw	Increased digestibility, higher protein content and increased intake
Fodder cultivation		
Grass, legumes, tree-crops, live fences	• Improved forage variety (berseem)	Increases digestibility and protein and energy content
Modified cropping patterns		
Dual purpose grains; thinning; stripping; mixed crops; forage trees (agroforestry)	• Leucaena tree leaves (2)	High digestibility and protein content

[1] Gotar is a mixture of pigeon pea leaves and empty pods.

[2] Figures in parentheses correspond to selected interventions in Table 6.

cropping patterns might also contribute to increased feed availability and/or quality (Relwani, 1983; Joshi *et al.*, 1995; Schiere *et al.*, 2004b). Some technologies originate in research centres; others may have been developed and/or substantially modified by farmers themselves (Sumberg and Okali, 1997). Appropriate targeting of (feeding) technologies for farmer groups is essential for effective research and extension (De Boer *et al*., 1994a). The technologies discussed in this chapter (Table 2) are based on a selection by a group of scientists and field workers, following a Participatory Rural Appraisal (PRA) exercise in the state of Gujarat (India). The state is largely agrarian in nature, with 50% of its area under cultivation. Average annual rainfall varies from 300 to 1,500 mm and the mean daily temperature varies from 15 to 42 °C. Smallholder mixed crop-livestock farming is predominant in Gujarat. The target group of smallholder dairy farmers is characterized by a land holding of approximately one hectare of rainfed cultivable land, and a herd of 2–5 animals: buffaloes, and predominantly local and crossbred cows. Hence, it was not only necessary to test the effect of feeding method, but also the possible interaction with existing breeding technologies (local and crossbred milk cows).

Crop residues, such as straw of paddy or sorghum, residues of pigeon peas (gotar) and dry grass comprise the basal diets of these animals. The animals are mainly kept for milk, draught and manure.

Case studies

Modelling studies were performed for three cases, varying in degree of complexity (Table 2). Case I looks at various price ranges in concentrate feed and milk for two farming systems, with crossbred and local animals, respectively. It aims at exploring the merits of concentrate feeding for different farming systems, based on a single criterion, i.e., marginal cost/benefit. Case II uses multiple criteria to evaluate the (side) effects of different supplementation strategies on herd performances. This implies three switches in focus in comparison to Case I. It shifts attention from single (monetary), towards multiple performance criteria, from animal to herd level as well as from short-term to medium and long-term effects. Case III uses whole farm planning to optimize total farm income, based on several criteria, allowing for interactions among farm activities. It assesses the merits of different feeding strategies and individual animal performances on total farm output and cropping pattern.

Table 2. An overview of technologies screened and modelling approaches used in the cases.

Modelling / Technology	Case I Concentrate feeding for dairying	Case II Supplements + treated straw for dairy herd[1]	Case III Level of milk/cow combined with feeding treated straw /leucaena leaves or crops
Basal feed	Poor quality roughage and dry grass	Straws	Straws and some tree leaves / roadside grazing
Straw treatment	No	Yes and no	Yes and no
Supplement	Several levels	Several levels and combination	Restricted
Animal breed[1]	Yes	Yes	Yes
System level	Cow	Herd	Farm
Criteria	Single	Multiple	Multiple
Context	Changes	Changes	Remains the same; but could be modified
Internal System	Remains the same	Remains the same / Changes	Changes
Modelling	Spreadsheet	PCherd (Udo and Brouwer, 1993)	Linear Programming (LP88)

[1] Animal breed is taken to be a local animal for low yield (up to 4–5 kg ha^{-1}), a cross-breed for medium yield (5–12 kg ha^{-1}) and higher (> 8–15 kg ha^{-1}).

Case I: Partial budgeting to screen for suitability of concentrate level and type of cow for milk production

Approach

This case uses a simple calculation via spreadsheets, to establish the marginal cost-benefit ratio of additional concentrate feed expressed in terms of returns from milk. It is a form of 'partial budgeting' (Amir and Knipscheer, 1989), a term used to stress the difference with 'whole farm' planning, as applied progressively in Cases II and III. This first case aims at assessing which farmers can decide on feeding of concentrates under varying costs of concentrates and prices for milk. It uses data from field conditions, i.e. local animals and crossbreds yield 0.58 and 1.28 kg of milk per kilo of concentrate, respectively (Patil and Udo, 1997a). This is much lower than indicated in

NRC (1986), i.e., one kg of concentrates with 650 g of total digestible nutrients (TDN) would yield 1.9 kg of milk, on the assumption that 350 g TDN is required for 1 kg of fat-corrected milk. The cost of concentrates was varied according to prevailing field conditions from 2.0 to 4.0 Indian Rs kg^{-1} and the milk price from 5 to 7 Rs kg^{-1}. Table 3 shows relatively higher costs of inputs and lower price of milk for farmers with local animals, that also tend to have limited access to the market. This situation is characteristic for the ethnically and socio-economically distinct 'tribals' in Gujarat (Masawi, 1988; Patil and Udo, 1997a, b).

Results

The results (Table 3) show that remote farmers with local cows under the assumed price conditions hardly benefit from feeding concentrates, except in the situations represented in columns 2, 3, 5 and 6. But three out of those four situations fall outside the likely price range for either concentrates (Rs 2 kg^{-1}) and/or milk (Rs 7 kg^{-1}). Hence, for this farm type, intensification appears not economically attractive, and the main option left is to produce whatever possible on roadside grazing and farm residues. However, farmers with better market access and crossbred cows may consider feeding of concentrates in all situations, with the conditions represented in column 7 being least attractive, but at the same time unlikely. The general trend of these results is confirmed by field observations, where farmers with market access and owning crossbreds realized higher gross income per kg of concentrate feeding (Rs 2.25) than those owning local animals (Rs 1.66) (Patil *et al.*, 1993). Annual net returns

Table 3. Partial budget calculations to explore whether and where farmers might have a niche for concentrate feeding (1US$ = 25 IRs).

Column number	1	2	3	4	5	6	7	8	9
Farmer remote from market (local cow)									
Price of 1 kg milk[1]	**5**	**6**	7	**5**	**6**	7	**5**	**6**	7
Cost of 1 kg extra concentrate[1]	2	2	2	**3**	**3**	**3**	**4**	**4**	**4**
Return in 0.58 kg milk	2.9	3.48	4.06	2.9	3.48	4.06	2.9	3.48	4.06
Gross income per kg of milk[1]	0.90	**1.48**	**2.06**	-0.10	**0.48**	**1.06**	–1.10	–0.52	0.06
Farmer with market access (crossbred)									
Price of 1 kg milk[1]	5	**6**	**7**	5	**6**	**7**	5	**6**	**7**
Cost of 1 kg extra concentrate[1]	**2**	**2**	**2**	**3**	**3**	**3**	4	4	4
Return in 1.28 kg milk	6.4	7.68	8.96	6.4	7.68	8.96	6.4	7.68	8.96
Gross income per kg of milk[1]	**4.4**	**5.68**	**6.96**	**3.4**	**4.68**	**5.96**	2.4	**3.68**	**4.96**

[1] Bold numbers represent most likely prices and higher gross income per kg of milk.

over feed cost per cow were also more favourable for crossbred cows (Rs 2,864) than for local cows (Rs –350) (Patil *et al.*, 1993). Patil and Udo (1997a, b) also reported higher gross margins for farmers owning crossbreds than for those owning local animals. This explains farmers' preference for crossbreds in conditions with a favourable milk/concentrate price ratio, and it illustrates the limitations of concentrate feeding where concentrates/milk ratios are unfavourable, due to prices, management and/or genetic potential.

Case II: Multiple criteria evaluation to screen suitability of feeding technologies

Approach

In this case, the impact of interventions on livestock production at herd level is explored. A simulation model (PCHerd) suitable for smallholder farming systems (Udo and Brower, 1993) is used to assess the effect of different feeding technologies on herd performance for the smallholder crop livestock systems in Gujarat. The model allows detailed calculations of feed intake, energy requirements, energy balances, weight gain, optimal weight, milk yields, traction, manure production, pregnancies, births, fertility, ageing, and mortality (Udo and Steenstra, 1996). Prevailing market prices and nutrient values of feeds, based on laboratory analyses (Table 4) were used. The technologies screened were supplementation, feeding of (treated) crop residues and tree leaves (Table 5). The milk price was set to Rs 6 kg^{-1}, the average of the price ranges used in Case I. Herd parameters used were nutrient balances (TDN and crude protein (CP)), production (milk yield, herd growth) and economic benefits (gross margins). Finally, farming systems were distinguished on the basis of access to

Table 4. Nutrient composition and prices of the feeds used in Case study II (based on Patil, 1996).

Feed	Crude Protein (CP) (%)	Total Digestible Nutrients (TDN) (%)	Price[1] (IRs kg^{-1})
Straw	4.0	50.0	0.75
Concentrates	18	65	1.85
Rice bran	12	60	2.80
Gotar	20.2	78	0.0
Leucaena leaf meal	26.2	75	1.60
Treated straw	9.0	55	0.90

[1] 1US$ = 25 IRs.

Table 5. Feeding interventions selected for simulation in Case study II.

Intervention	Description
0	Actual situation
1	Urea-treated rice bran and gotar[1]
2	Leucaena leaf meal
3	High levels of concentrates
4	Urea-treated straw + medium levels of concentrates

[1] Gotar is a mixture of pigeon pea leaves and empty pods.

Table 6. Farming systems used in Case study II. Tribal and non-tribal farmers were combined in FS1 and FS2, because of their similarity in herd size and land holding when owning crossbreds (based on De Jong, 1997).

Farming system	Social category	Access to land	Breed of cows	Herd size[1]	No. of cows
FS1	Tribal *and* non-tribal	Yes	Crossbreds	6 (1)	4
FS2	Tribal *and* non tribal	No	Crossbreds	3 (1)	2
FS3	Tribal	Yes	Local	5 (1)	3
FS4	Tribal	No	Local	3 (1)	2
FS5	Non-tribal	Yes	Local	7 (1)	4
FS6	Non-tribal	No	Local	3 (1)	2

[1] Figure in parentheses indicates no. of calves.

resources, such as land, type of animal, i.e., local or crossbred cattle and social class, i.e., tribals and non-tribals (Table 6). Simulations were performed over a period of two years. On account of random elements (conception, mortality), 40 runs were executed for each farming system – feeding intervention combination. Simulation results were compared for each farming system for consumption of feeds, animal production, mortality, reproduction and energy and protein balances.

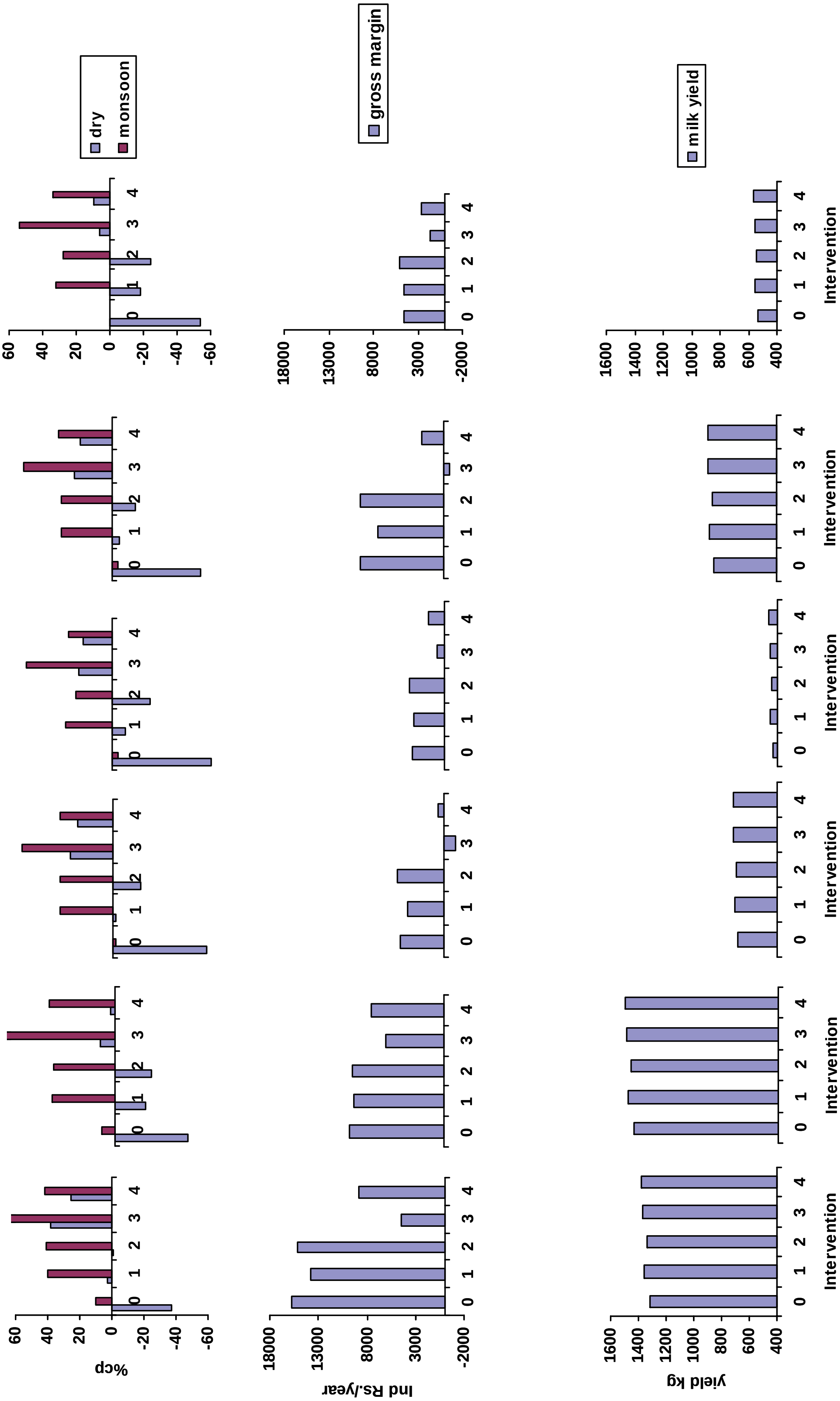
Results

Nutrient balances at herd level. Simulation results (Figure 1) reveal energy shortages (TDN) under current conditions for all farm types, substantial (up to 27%) during the dry season and marginal (<8%) in the monsoon season. Protein shows a similar picture for the dry (>55%) and monsoon (<8%) seasons, except for FS1 (tribal and non-tribal farms with crossbreds and land) and FS2 (tribal and non-tribal farms with crossbreds and no land) that show slightly positive balances in the monsoon season. Hence, both energy and protein appear to limit animal performance, especially in the dry season. All feeding interventions tested improve the situation, but positive balances for energy in the dry season are attained only with supplementation with urea-treated rice bran and gotar (except for FS2 and FS6 (non-tribal farms with local cows and no land)) and high levels of concentrates (except for FS2), while medium levels of concentrates with urea-treated straw result in positive balances for crossbred cows (FS1 and FS2). In the monsoon season most interventions result in positive energy balances, except for the crossbreds in landless systems (FS2) and the leucaena meal for the local cows in tribal grazing systems (FS3, tribal farms with land and local cows).

In terms of protein supply, all tested interventions lead to positive balances for all systems in the monsoon season. In the dry season, positive balances are attained for all systems with supplementation of high levels of concentrates (3) and of urea-treated straw and medium levels of concentrates (4), while for crossbreds under grazing also supplementation of urea-treated rice bran and gotar (1) and leucaena leaf meal (2) lead to positive balances.

Milk production and herd growth. Milk yields vary considerably among farm types, with crossbred cows having by far the highest yields, and those from landless farms producing 100 to 150 kg more per lactation than those from farms with land. Herd growth increases substantially as a result of the feeding interventions at farms with land and crossbred cattle and on landless farms with local cattle (increases of 16, 24 and 26% for FS1, 4 and 6, respectively). Supplementation with high levels of concentrates, with urea-treated rice bran combined with gotar and with urea-treated straw combined with medium levels of concentrates are most effective (interventions 3, 1 and 4 give increases of 22, 19 and 17%, respectively). These higher herd growth rates are associated with higher conception rates due to the relatively favourable body condition of the animals.

Gross margins. Gross margins are higher for farms with crossbreds (Rs 4,409 to 15,719) than for those with local animals (Rs –1,311 to 8,848), due to higher milk yields (Figure 1). Feeding interventions based on local resources, such as leucaena leaves and urea-treated rice bran with gotar (interventions 1 and 2) hardly affect gross margins. Supplementing with high levels of concentrates or with urea-treated straw and medium levels of concentrates (interventions 3 and 4) substantially reduce gross margins for all farm types.


FS1
FS2
FS3
FS4
FS5
FS6
dry
monsoon
gross margin
milk yield
%cp
Ind Rs./year
yield kg
Intervention

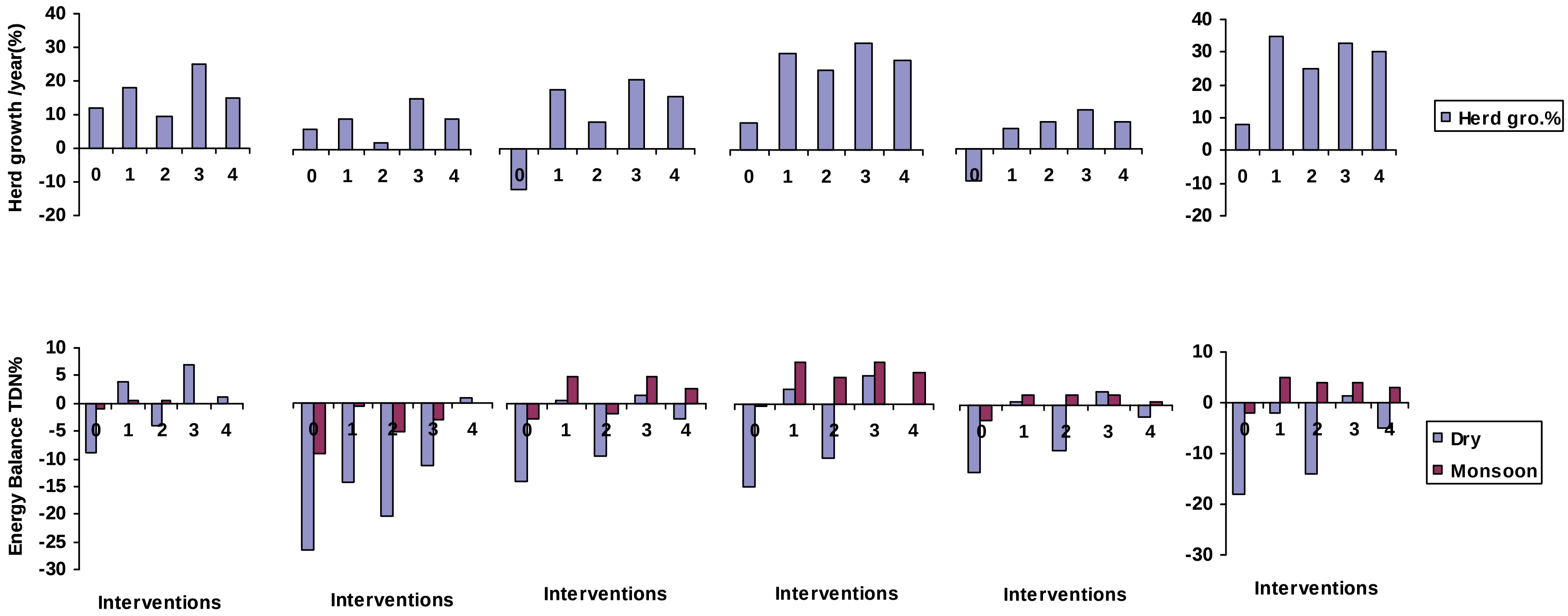


Figure 1. Simulation results of PCHerd for effects of different feeding technologies (see Table 5 for definition) on nutrient balances (crude protein, CP, total digestible nutrients, TDN), gross margins, milk yield and herd growth per farm for different Farming Systems (FS, see Table 6 for definition).

Case III: Whole farm analysis to screen feeding technologies

Approach

This case represents a simple form of whole farm planning using linear programming. It examines how animal production levels, feeding technologies and cropping patterns can be combined in an optimal way for a hypothetical, but realistic mixed crop-livestock farming system in the target area (Patil *et al*., 1993). The system resembles the ones of Cases I and II which combine livestock and (cash) crop cultivation for rainfed conditions around Baroda, agro-ecological Zone 3 in Gujarat (Ghosh, 1991). Methodologically, the study comprises a set of runs of very simple LP matrices (Schiere *et al.*, 1999a). Solutions are different for different quality feeds or for cows of different production levels. Examining a number of runs results in a range of solutions, rather than in one optimum solution. In various runs, farm gross margins, number of animals and individual crop yields are optimized in a cropping system with locally preferred crops, in this case sorghum and cotton. The model also maximizes total and individual milk yield that could be sustained with available feeds, breeds and cropping patterns. Two alternatives are studied in the model: (i) urea treatment of stover (TS) compared with untreated stover (UT) and (ii) leuceana leaves supplementation with (3 kg d^{-1} cow^{-1}) and without concentrate supplements (Tables 6 and 7).

Results

The results show that in systems based on treated stover, the best combination uses mixed farming, with a total farm milk production of 10.6 kg d^{-1}, obtained from animals with a daily yield of 10 kg (Table 7). When introducing higher-yielding animals, the model shows a shift in cropping system, i.e. beyond a milk yield of 10.6 and 14.0 kg d^{-1} for untreated and treated straw, respectively, cotton replaces the grain crop. This is an unexpected result, the reason being that more productive animals require better quality feed than available in the form of sorghum stover. Without use of stover for the production of milk, income from sorghum (grain only) is lower than that from cotton, assuming no other opportunity benefits for stover or cotton stalks.

The LP model also shows whether crude protein content or energy (TDN) is limiting in the on-farm feeds. It suggests the need to increase CP in the ration in the milk production range: of 6–16 kg cow^{-1} d^{-1}. This could be done by adding protein-rich tree leaves, forages, urea treatment of stover or concentrates. Additional energy (TDN) is required at production levels below 8 kg of milk cow^{-1} d^{-1}. Urea-treated stover (TS) feeding appears to support higher numbers of animals and results in higher total production per farm (Table 7). However, feeding of TS had little effect on total system output with low-yielding cows.

Table 7. Optimum crop combinations, herd size and individual animal yields (breed) with or without treatment of stover (TS *vs* US). **Bold** indicates highest value in the column, underlining indicates the value pertaining to the highest gross farm income.

Individual animal* production ($kg\ d^{-1}\ cow^{-1}$)	Total production ($kg\ d^{-1}\ farm^{-1}$)		Herd size ($animals\ farm^{-1}$)		Cotton area (ha)		Total gross income milk and crops ($IRs\ d^{-1}\ farm^{-1}$)	
	US	TS	US	TS	US	TS	US	TS
0.3	1.0	1.1	**3.5**	**3.6**	0.0	0.0	10.5	10.5
2.0	5.1	5.6	2.5	2.8	0.0	0.0	22.2	23.8
4.0	7.8	9.2	1.9	2.3	0.0	0.0	30.4	34.4
6.0	9.5	11.6	1.6	1.9	0.0	0.0	35.4	41.7
8.0	10.6	13.0	1.3	1.6	0.0	0.0	38.9	45.9
10.0	**10.6**	**14.0**	1.1	1.4	0.4	0.0	**39.1**	**49.0**
12.0	10.4	12.9	0.9	1.1	0.8	0.4	38.9	45.9
16.0	6.6	6.6	0.4	0.4	**1.0**	**1.0**	27.6	27.6

* Local cow: ≤ 4 $kg\ d^{-1}$, Cross bred cow: 6–16 $kg\ d^{-1}$.

Table 8. Identification of limiting nutrients for milk production in Leucaena + 3 kg of concentrate supplements at different levels of milk production (adapted from Patil *et al.*, 1993).

Individual animal* production ($kg\ d^{-1}\ cow^{-1}$)	Production ($kg\ d^{-1}\ farm^{-1}$)	Herd size	Total gross income milk and crops ($IRs\ d^{-1}\ farm^{-1}$)	Surplus CP[1] ($kg\ d^{-1}$)	Surplus TDN[1] ($kg\ d^{-1}$)
0.3	0.8	2.6	8.8	0.26	0.00
2.0	4.0	2.0	18.2	0.15	0.00
4.0	6.5	1.6	25.7	0.08	0.00
6.0	8.2	1.4	30.9	0.03	0.00
8.0	9.4	1.2	34.6	0.00	0.03
10.0	10.2	1.0	36.8	0.00	0.21
12.0	10.7	0.9	38.1	0.00	0.18
16.0	8.00	0.5	31.1	0.27	0.00

[1] CP = crude protein; TDN = total digestible nutrients;

* Local cow: ≤ 4 $kg\ d^{-1}$, Crossbred cow: 6–16 $kg\ d^{-1}$.

Discussion and conclusions

In the three case studies in this chapter, the suitability of various feeding and breeding techniques in low input systems has been explored. The simple partial budgeting study in Case I clearly indicates the existence of niches for concentrate supplementation. Especially farmers with better market access and owning crossbred cows can benefit from feeding concentrates, except in the unlikely condition of high concentrate prices (> Rs 4 kg^{-1}) and low milk prices (< Rs 4 kg^{-1}). Hence, some farmers are structurally disadvantaged due to poor market access. Distance to the market is reflected in a cost and price gradient for concentrates and milk, a common situation in many places around the world (Owango *et al*., 1998). However, feeding cannot be seen in isolation of animal production level and herd performance. In Case II, results of herd simulations show that differences in milk yield, herd growth and gross margins are larger between farms with crossbred cows and local cows than between different feeding strategies at a given farm structure. The results indicate that crossbreds are more remunerative for landless and tribal farming situations, in agreement with field observations by Patil and Udo (1997a, b). Interventions in feeding systems more strongly affect production parameters on farms with crossbreds than on those with local cows, again illustrating the more limited potential of local animals. The calculated nutrient balances are in agreement with observations of Patil and Udo (1997a, b) for the dry season, but differed for the monsoon season when crude protein was still deficient and energy balances were positive. This could be due to the fact that in PCHerd the nutrients are also used for conception, growth of young animals and body condition of mature animals. Patil and Udo (1997a, b) ignored body condition and conception. in analysing the field data for individual cows. The use of multiple criteria in this analysis can serve to set research/extension priorities, as it identifies limiting factors, which can be discussed with local stakeholders such as extension workers, scientists and the farmers.

Case III focuses on the suitability of technologies by taking into account the relations on a mixed crop-livestock farm. The results show that so-called improved feeding technologies lead to higher production levels, provided '*breeding tallies with feeding*'. However, introduction of very high-yielding cows can be counter-productive, as they cannot use the low quality feeds available on the farm. This indicates, at first rather counter-intuitively, that introduction of more productive cows can result in lower total farm income, because of the lower monetary value of the grain crop, when the straw cannot be used. This leads to a shift in cropping pattern due to adoption of a new technology, such as high-yielding cows. This illustrates that a change in one place can have unexpected effects elsewhere. Urea treatment of straw results in modest additional income at low yields, which agrees with results from Schiere and Nell (1993).

Feeding interventions, such as use of concentrates, urea supplementation with rice bran and gotar, leuceana leaves, urea-treated straw with limited concentrates, could benefit farms with crossbred cows. Gotar feeding is feasible in Zone 3, where farmers cultivate pigeon pea. Tree leaf-feeding is feasible for farmers with access to tree leaves and slack labour, such as for tribal and landless farmers. However, urea-treated straw with limited concentrate supplementation may not be suitable for non-descript cows and/or landless farmers due to limitation of straw availability and low milk yield of the cows.

No attempt was made in this chapter to systematically compare the advantages and disadvantages of the three modelling approaches. However, following the analyses, we feel more confident that partial budgeting is indeed useful to screen interventions, such as concentrate feeding to milking cows, for their contribution to short term gains. PCHerd is useful for exploring the effects of interventions on long-term performance of the herd. Linear programming appears useful in more complex situations of whole-farm planning to maximize farm income from crop livestock combinations. Modelling is thus a useful tool for FSR workers that aim at examining the suitability of on-the-shelf technologies, to avoid expenses in real-life experimentation, e.g., in terms of money, labour, time and motivation. The selected modelling tool will depend on the farm situation, the farmer's objective, and the complexity of the technology in terms of its effects on farm structure and management. A basic message in terms of paradigm is that these three modelling approaches illustrate a shift from reductionist to more holistic approaches. In other words, the first one examines one intervention on one single criterion (income) in different contexts. The second one examines the effect of feeding and breeding interventions on herd performance. The third looks at the combined effect of animal feed and breed on whole farm performance.

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CHAPTER 6

Technology transfer for mixed crop-livestock farms: Experiences with field experimentation

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Summary

Effective extension for (livestock) development depends to a large extent on the proper identification, testing and modification of technologies. This chapter uses narratives and quantitative/qualitative cases to describe the experiences of BAIF, a large NGO in India, with a large number of and variation in field experimentation at the level of animal, plot, farm, and watershed. The work took place over a period of roughly 30 years, divided into three phases, starting with a period of predominantly top-down approaches, moving to a second phase with participatory identification and testing of technologies, and into a third phase with work at community and watershed level. A few cases are discussed for each phase, illustrating the processes, methods and type of technology involved, and helping to draw lessons on field experimentation for livestock and farm development in general.

Introduction

Agricultural development is affected by many factors, such as farmers' access to resources, availability of knowledge and skills, consumer demands, national and international policies and social aspects. Livestock development is no exception to this rule, and as a result, a large number of technologies for crop-livestock systems are not readily accepted across the board (Jackson, 1981; Conway and Barbier, 1990; Schiere, 1993; Udo, 1995; De Jong, 1996; Devendra, 2000). Indeed, low adoption rates of technologies by farmers are at least partly due to differences among farmers in terms of their access to resources, such as land, water, livestock and credit and personal values, status, food habits, and to cultural barriers. Many development programmes lack a proper perspective on the local resources, the environment and the needs of the farmers (Van den Ban and Hawkins, 1988; Chambers *et al*., 1989; Röling, 1996). What is useful for one farmer may not be useful for another, and certain technologies can even have negative trade-offs. Awareness of this situation led to the development of Farming Systems Research (FSR) techniques, of which field testing of technologies is an important component (Shaner *et al.*, 1982; Fresco, 1986; Conway and Barbier, 1990; Collinson, 2000). One form of field testing is on-farm trials (OFT). Its primary purpose is to provide feedback in terms of farmers' perceptions on technology to extension workers, planners, researchers and development agencies (Shaner *et al.*, 1982; Amir and Knipscheer, 1987; Mettrick, 1993; Yazman *et al*., 1994; Sumberg and Okali, 1997).

BAIF (BAIF Development Research Foundation), a large Indian NGO, working for development of the rural poor since the early 1970s, has tested over 200 different technologies in the field of crop and livestock production and off-farm activities to suit the conditions of resource-poor farmers. Some of these were successful, others were not, and none was successful across the board. Over the years, the interventions were chosen and planned through a mix of top-down and participatory methods, they dealt with scales from plot and animal to farm and region, and were intended for short- and long-term action. Identification of method and technology varied, depending on government policies, specific local conditions, farmer priorities and stage of development. In this chapter, the livestock development programme of BAIF is schematically sub-divided in three phases to discuss the experiences from approximately the mid-1970s till today (Table 1). For each phase, some cases are discussed that are typical for the approaches in that particular period, and the last section draws lessons from all cases. The cases deal with aspects of improving the breed, and/or nutritional status of dairy animals in Gujarat, and improvement of crop productivity (e.g., soybean), and watershed development under rain-fed conditions in Gujarat and Madhya Pradesh. Agro-climatic data are given in Chapter 1 of this thesis. This chapter presents narrative, quantitative and qualitative analyses.

Three phases and different forms of field experimentation

BAIF's field work in the first phase consisted of a rather blanket approach that promoted crossbreeding more or less regardless of agro-ecological and socio-economic characteristics of the cattle owners as described by Rangnekar (1989) and in other chapters in this thesis. The initial success of this programme led to the

Table 1. BAIF's experiences in technology transfer, a summary.

Technology	Year (approx. started)	Constraints for adoption	Key solutions	Approx. degree of adoption*
Animal level				
Breeding				
Artificial Insemination, crossbreeding	1970-till to date	Ignorance Access Perception Lack of resources Farmers' choice	Enhancing farmers awareness Services at doorstep Input supply	60-80%
Improving other breeds of cattle, buffaloes, goats	1990	Lack of resources	Input supply	20-60%
Feeding				
Improving feed quality -Straw treatment -Tree leaves -Forage production -Urea molasses -Urea molasses granules	1975 1993 1993 1978 1975 2000	Limited resources Lack of knowledge Weak extension	Input supply Effective extension Training and participatory research	 0% 20-40% 20-30% 40-60%
Health care				
Preventive vaccination	1974	Lack of resources and availability	Input supply	60-80%
Disease diagnostic services	1978	Lack of resources and availability	Providing diagnostic and referral services	40-60%
Crop level				
Improved varieties	1999	Non-availability Lack of awareness Preference Limited resources	Input supply Extension and demonstration, OFT	60-80%
Integrated Pest Management (IPM) Integrated Nutrient Management (INM)	2001 2000	Lack of awareness Lack of resources Non-availability	Extension, Demonstration, OFT, Input supply and credit Participatory research	20-40% 20-40%
Watershed level				
Water resource development and use	1994	Limited resources Ignorance Lack of community participation	Credit availability Extension Demonstration, OFT Participatory research Community empowerment	60-80%
Soil conservation	1995	Lack of knowledge and resources Lack of community participation	Community empowerment	40-60%

* Adoption responses are based on estimates from surveys, group meetings with farmers and BAIF staff, monitoring and impact assessments of BAIF's field programme.

emergence of new problems in development, i.e., to a need for additional support activities, such as provision of fodder packages, feed supplements, health measures and training of livestock keepers to acquire the required skills for crossbreeding. The second phase focused on more participatory approaches at farm level. Farmers' participation was encouraged through joint actions for constraint analysis, identification of technologies, and participatory farm experimentation. One of the side-effects of such participatory work was the need to find a new balance between livestock and crop research, a reason to also report work on crops in this chapter. Eventually, BAIF moved into a third phase, including watershed development and community work, among others because the participatory approach revealed problems at higher scale, such as water shortage for the community.

BAIF now develops and tests technologies at various scales with farmers, while carrying out development activities to increase the productivity of crops and livestock and family income. The trials are now designed and monitored by both scientists and extension workers, while mainly being carried out by the farmers themselves, so-called 'farmer-managed' (Mettrick, 1993). The farmers involved in experimentation provide their perceptions on various aspects of the technology.

Phase I: The initial top-down approach and the early work on crossbreeding

Case Ia A narrative on the crossbreeding work

BAIF initiated its development work in the early 1970s in rural areas of western Maharashtra by introducing crossbreeding through AI to increase milk production (Table 1). Sugar cooperatives supported this initiative to benefit their member farmers. The programme was based on the doorstep delivery and use of imported semen of Holstein-Friesian and Jersey bulls in a cluster of 10 to 15 villages. A few years later, the state government also started to support such cluster-based breeding services in other areas, trying to copy the success of one region in others, but adoption was limited in some remote areas, even if the service was free. Various deliberations with field functionaries and the farmers on causes of the lukewarm response revealed reasons such as weak communication, farmers' perceptions on 'unnatural' breeding, doubts on conception from frozen semen, reservations on the performances of the progeny, disease resistance and loss of local germplasm. This informal gathering of feedback helped BAIF to modify the approach. For example, various communication mechanisms and means, based on local conditions, were introduced to overcome the difficulty of poor communication in remote areas obstructing accessibility of AI technicians. Location-specific communication systems were developed where no communication network or milk procurement system existed. Means, such as messages through the postman who daily visited headquarters (HQ), or notes from farmers to the technician at HQ via bus passengers going to markets or via a private milkman or in some places messages were collected at a fixed place such as a tea shop, and use of telephone services where available. In some cases, motivational incentives were paid to messengers and regular fixed-time visits were organized by AI technicians where no such means were available. In addition, to attend to issues of negative farmers' perceptions regarding crossbreeding and AI, group meetings, trainings and exposure visits of opinion leaders and farmers were organized to nearby cattle breeding farms, where BAIF already provided services to improve their herds. Special extension material, such as leaflets, posters, and audio visuals in local languages were used to motivate the farmers to make use of the services. And slowly, but surely, farmers started adopting the new technologies to the extent that in some areas additional support services were established to cope with the work. Later, increased awareness among the farmers and increased expectations led to introduction of other support services, such as preventive health coverage, fodder promotion, and trainings in management of calves and dairy animals. *Ex-post* surveys and performance monitoring of the crossbreeding programme helped to convince the policy makers of the need for government support for expansion (Chapters 3 and 4).

Case Ib Promoting fodder cultivation

Very few large farmers and almost no small farmer cultivated fodder crops in Gujarat at the start of the crossbreeding programme. The need for additional fodder in association with crossbreeding, however, drew BAIF into promotion of fodder cultivation. Therefore, during the late 1980s, with the support of local government, (free) fodder seed packages were supplied to small farmers. These packages contained seeds of so-called improved varieties of cowpea, maize and sorghum, with the required doses of fertilizer for 0.1 ha, and were supplied to two to four farmers per village, depending on its size. A total of 2400 seed packages were supplied every year for three years at 60 centres, a top-down target-oriented action. Orientation and information on cultivation and its benefits in the local languages were provided along with the packages. Supplies and orientation were made available before the onset of the monsoon in the first year. The first round of assessment of performance of the packages showed that performance and yields were quite encouraging, but around a quarter of the seed packages was not used. Then it was decided that extension workers would revisit the farmers for feedback on their non-adoption behaviour. Surprisingly, priority of the farmers for crops such as cereals over fodder and ample availability of green material during the monsoon season from nearby common lands were the main reasons for non-adoption. Indeed, this was a lesson to BAIF: the top-down approach ignored farmers' priorities and overlooked the real situation of fodder availability. Feedback from farmers on their priorities, such as the need for additional forage in winter (rabi season) led to modification of the forage promotion activity to winter, with a choice to opt for the other seasons. More than sixty percent, at some centres even all, of the farmers opted for the winter package of oats and the winter variety of sorghum. Farmers appreciated this change in approach and its results. Around 30% continued harvesting seeds for cultivation in the following year without support, and some even sold seeds to other farmers.

Phase II: Participatory and more quantitative work with on-farm experiments

BAIF encourages its research- and development staff to participate in seminars and workshops, and to be involved in national and international collaborative projects with research institutions such as the National Development Research Institute (NDRI), Indian Council for Agricultural Research (ICAR), International Livestock Research Institute (ILRI), and national and foreign universities. Through these activities, BAIF scientists and extension staff are routinely exposed to on-station proven technologies. During the annual planning meetings, appropriate technologies that might be useful to farming communities are given special attention. Experiences on constraints and solutions related to some of the most widely used and accepted technologies are summarized in Table 1.

During this phase, a series of consultations were held between scientists, extension workers and farmers on availability and costs of local resources, types of animals and farms prior to on-farm experimentation (OFT) design. There was also a move to more formal, quantitative, but less top-down and target-oriented approaches of on-farm research than in phase I. On-farm experiments were designed '*with and without*' and '*before and after*' interventions in Case I, '*before and after*' in Case II, and '*with and without*' in Cases III and IV (Table 2). Methods were selected on the basis of availability of homogeneous groups of animals and farms (for instance, '*with and without*' requires larger numbers of animals than '*before and after*'), distance, labour, logistic support and feed resources.

Table 2 Methods adopted for interventions in OFTs.

Method	With and without	Before and after	With and without + Before and after
Treatments	Testing soybean varieties Case III Soil and water conservation measures, Case IV	Urea treatment of straw Case II	Supplementation strategy Case I

Qualitative and quantitative assessments of the new technologies or methodologies were performed using conventional statistics, ranking and cost-benefit analyses. Assessment criteria were biological, such as milk production and feed intake, economic such as costs and benefits and farmers' perceptions on production systems and labour distribution between men and women.

In the rain-fed farming systems conditions of Gujarat, feed availability for livestock is problematic during the dry season from November to June. Studies in such systems suggested that rations for crossbred animals were deficient in both, protein and energy during the dry season (Patil *et al*., 1993). Many on-the-shelf technologies are available on supplementation of low quality rations (Preston and Leng, 1987; Kiran Singh and Schiere, 1995; Joshi *et al*., 2003), but the use of supplements is often considered to be costly and/or labour-intensive or supplements are not available (see also Case I of Chapter 5). As a result, feed technologies have had little or no impact on production at farm level as also observed by Udo and Cornelissen (1998).

Case IIa Supplementation strategies

Two on-farm trials were carried out in villages from Baroda and Panchamahal districts in zone 3 of the Gujarat plains and hills (Chapter 2). Participants were smallholders with mixed crop-livestock farms of 4-6 head of cattle or buffaloes and rain-fed crop production. Twenty-five farmers were selected (mostly with only one lactating crossbred cow), with 12 animals in the control group and 14 in the treatment group in Trial A, a group of 40 farmers with 12 and 28 cows, respectively in Trial B. Holstein-Friesian crossbred (F_1) cows were selected, in their 2^{nd} to 4^{th} lactation, between 60 and 150 days after calving, and producing 4 to 15 kg milk per day.

In Trial A, the basal ration was supplemented with 50 g d^{-1} urea per animal, mixed with 500 g rice bran and 1500 g gotar (pigeon pea leaves and pods). In Trial B, the supplement consisted of 500 g d^{-1} rice bran and 1500 g d^{-1} leucaena leaf meal. All supplements were provided by BAIF. The urea was weighed and packed in small polythene bags for daily feeding. The farmers, both husbands and wives, were trained in feeding of supplements, record keeping and weighing bran, leaf meal and gotar by using local baskets, bowls and tins. Feeds were analysed at the BAIF feed analysis laboratory in Uruli Kanchan (Table 3).

Crude protein (CP) requirements were assumed to be 5 g per kg metabolic body weight and 87 g per kg milk (NRC, 1986). Body weights were estimated at 375 kg on average (Patil and Udo, 1997a).

Both trials lasted 10 weeks with an adaptation period of 2 weeks (P1), an experimental period of 6 weeks (P2) and 2 weeks post-supplemental (P3). The control group was fed, throughout, according to farmers' usual practices, as were all animals before

Table 3. Composition of feeds in feeding trials.

Feed component	Dry Matter content (%)	Crude Protein content (%)	Price (Rupees/kg)	
			Trial A	Trial B
Dry forages	89	3.1		
Green forages	25	5.6		
Concentrates	90	14.4	3	3
Urea	n.a.	46 (N)	3	3
Rice bran	92	14.5	2.20	2.80
Gotar (pigeon pea leaves and pods)	91	10.0	--*	
Leucaena leaf meal	92	22.9	n.a.	1.60
Milk			5.50	6

* farm produce.

and following the experimental period. Farmers measured the amounts of the different feeds (dry forage, green forage and concentrates) offered and refused, as well as milk production at weekly intervals during P1, P2 and P3. BAIF extension workers monitored the trials by weekly visits to the farms. Cost-benefit calculations were based on the costs of supplements and revenues from milk. For trial A the costs of rice bran and urea were Rs 2.20 kg^{-1} and Rs 3.00 kg^{-1}, respectively (1 US$ = Rs 48; currency calculated in 2004). Gotar was available at the farm as crop by-product, opportunity costs were estimated at Rs 1.20 kg^{-1}. For trial B, the costs of rice bran and leucaena leaf meal were estimated at Rs 2.80 kg^{-1} and Rs 1.60 kg^{-1}, respectively. The costs of commercial concentrates were Rs 3.00 kg^{-1} and milk prices were Rs 5.50 kg^{-1} and Rs 6.00 kg^{-1}. Farmers' perceptions of the effects of supplementation and required management practices were recorded. The degree of adoption was evaluated by BAIF extension workers that visited the farmers one year after completion of the trials.

Statistical analysis showed that milk yield increase during the experimental period (D1) was significantly ($P<0.01$) higher for the group with supplements (+0.9 kg cow^{-1} d^{-1}) than for the control group (–0.5 kg cow^{-1} d^{-1}) (Table 4) in trial A. Milk yield during P2 was significantly ($P<0.05$) higher than the mean of P1 and P3 (D2). Similar results were found in Trial B, although the differences between the two groups were smaller and only significant for D1. Thus, when comparing P1 and P2, the supplements increased daily milk production by about 0.9 kg cow^{-1} d^{-1} in Trial A and by 0.8 kg in Trial B. In both trials, less concentrates were fed to the experimental cows in the supplementation phase (P2) than in P1 and also less than to the control cows in P2. Apparently, farmers tried to save on concentrates while feeding supplements.

Table 4. Average milk yield (kg cow^{-1} d^{-1}; values in parentheses are standard deviations) before (P1), during (P2), and after (P3) supplementation with urea, rice bran and gotar (Trial A), and rice bran and leucaena leaf meal (Trial B).

	Trial A			Trial B		
Supplements	Yes	No	Prob.[1]	Yes	No	Prob.[1]
Number of animals	13	12		28	12	
Period 1 (P1)	5.5 (1.26)	5.9 (2.24)		7.3 (4.47)	7.9 (2.85)	
Period 2 (P2)	6.4 (1.48)	5.4 (1.77)		8.1 (4.52)	7.8 (2.94)	
Period 3 (P3)	5.9 (1.09)	5.0 (1.46)		7.5 (4.68)	6.9 (2.87)	
D1 = P2-P1	0.9 (1.14)	–0.5 (0.98)	**	0.8 (0.44)	–0.1 (0.71)	**
D2 =P2–(P1+P3)/2	0.7 (0.75)	0.0 (0.60)	*	0.7 (0.41)	0.4 (0.36)	ns

[1] Probability of difference between groups with and without extra supplements: ** P<0.01; * P<0.05; ns P>0.5.

Costs of: rice bran = Rs 2.20 kg^{-1}, urea = Rs 3 kg^{-1}, concentrates = Rs 3 kg^{-1}, and milk = Rs 5.50 kg^{-1} for trial A and costs of rice bran = Rs 2.80 kg^{-1}, leucena leaf meal = Rs 1.60 kg^{-1}, concentrates = Rs 3 kg^{-1}, milk = Rs 6 kg^{-1} for trial B.

The costs of supplements were Rs 1.25 cow^{-1} d^{-1} in Trial A and Rs 3.80 in trial B. If opportunity costs for gotar are added, total costs increase to Rs 3.05. During P2, Rs 1.50 cow^{-1} was saved on concentrates in Trial A and Rs 0.60 in Trial B. Total costs of supplementation are then Rs 1.55 and Rs 3.20 cow^{-1} d^{-1} in Trial A and B, respectively. The value of the additional milk in P2 was (compared to P1) Rs 7.7 and 5.4 cow^{-1} d^{-1} in Trial A and B, respectively, and compared to the average of P1 and P3, Rs 3.9 and 1.8 cow^{-1} d^{-1}, respectively when compared to the control.

Of the farmers using supplements in both trials, 90% realized that supplementation increased milk production, while 83% said that the health status of the cows also improved, as judged from their physical condition. The farmers appreciated the use of local measuring tools (bowls, baskets and tins), and the pre-packaged daily urea doses that made them easy to mix with the bran. However, at the start, all farmers had reservations about feeding urea. Some were aware of the danger of urea poisoning, and fed only half the recommended dose for the first few days. Most farmers (68%) found the supplementation methods easy to adopt because they required only minor changes in their routine practices, and because urea is widely available, according to the experimental farmers in Trial A. More than half (61.5%) of these farmers continued feeding urea and rice bran, and almost all farmers had continued feeding gotar to the lactating animals, when they were revisited after one year. Availability of leucaena leaves was a major constraint reported by all farmers, but whenever possible, they fed it to the lactating animals. Mainly women were involved in feeding (81%), milking (88%) and watering (72%) (Figure 1); they perceived the increase in workload due to supplementation as negligible. They also noticed no change in dung consistency, an important point, as they make dung cakes for cooking. Neighbouring farmers showed interest in the trials and many started feeding gotar and leucaena leaves to their milking and draught animals.

Case IIb Urea treatment of crop residues

Treatment of straw with urea is an effective means of increasing digestibility and crude protein content of cereal straws (Schiere and Ibrahim, 1989; Sharma *et al.*, 1995). Field experience, however, indicates that various factors influence adoption of urea-treatment by farmers. BAIF therefore tested the response of feeding urea-treated (4% w/w) paddy (UTPS) and wheat straw (UTWS) to crossbred cows in Zones 3 and 6 of Gujarat under rainfed and in Zone 1 (Surat, Gujarat plain and hills) under irrigated conditions (Chapter 2). Paddy straw treatment was tested on 24 farms in Zones 1 and 3, and wheat straw treatment on 11 farms in Zone 6.

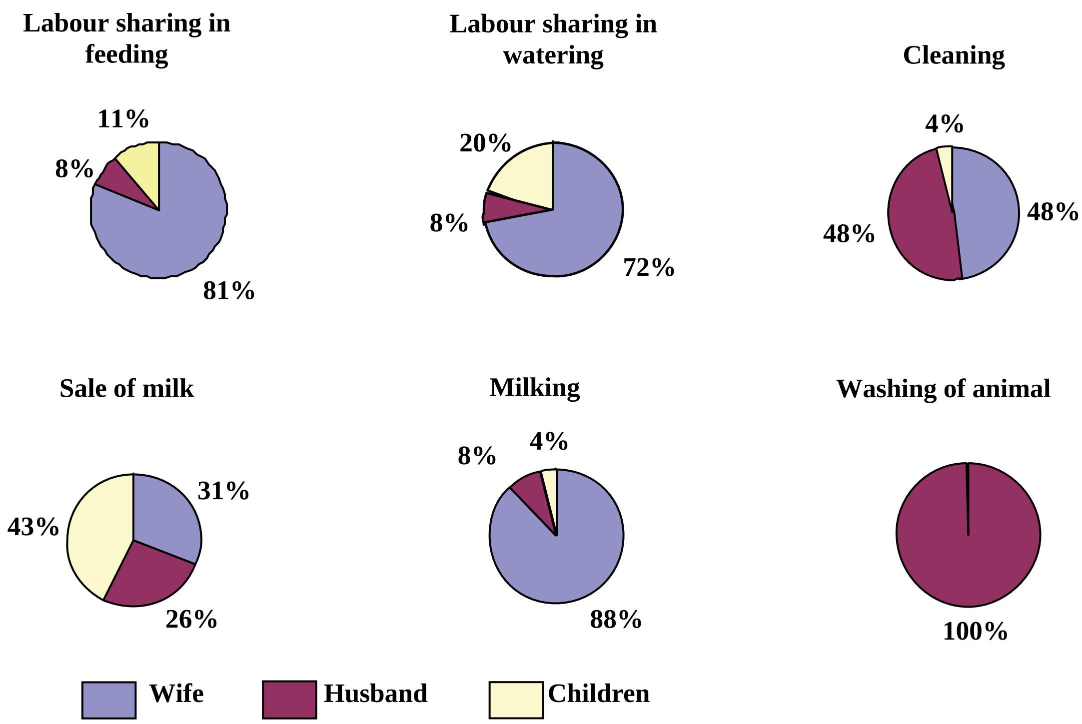

Figure 1. Labour division in animal management.

On each farm, one crossbred cow, Holstein-Friesian or Jersey crossed with Gir or Kankrej, in the third to fifth month of lactation, with milk production from 6 to 12 kg daily, was fed the urea-treated cereal straw for six weeks, while all other management practices remained the same. Green feeds in Surat consisted primarily of sugarcane tops, in other districts of weeds and some sorghum. Milk production and intake of straw, concentrates and fodder were measured and farmers' perceptions were recorded weekly for two weeks before (P1) and after (P3) a six-week experimental period (P2). The periods before and after are considered as 'control'. Simple means, cost-benefit analyses and farmers' perceptions and attitudes were used for assessment of the technology

All cows showed a positive response to feeding of treated straws. Milk yield during the experimental period with UTPS increased from 0.3 kg cow^{-1} d^{-1} on the rainfed farms to 2.1 on the irrigated farms of Surat (Table 5), with a weighted average of cows across Zones 1 and 3 of 1.0 kg cow^{-1} d^{-1}. Cows fed urea-treated wheat straw increased milk yield by 0.4 kg cow^{-1} d^{-1}, ranging from 0.3 to 0.6 kg. Straw consumption increased from 4% for UTWS to 39% for UTPS. Farmers were allowed to adjust feeding of concentrates and green fodder during the entire 10-week trial period. The change in concentrate use was negligible in all districts, except in Surat, where farmers actually increased concentrate feeding by 0.5 kg per day to support the higher production.

The cost of the urea treatment was Rs 0.19 and 0.24 kg^{-1} for paddy and wheat straw, respectively. Total daily costs of urea treatment per cow were Rs 1.74 and 2.20 for paddy and wheat straw, respectively. The value of the additional milk was Rs 5.00 and 2.28 cow^{-1} d^{-1} for paddy and wheat straw, respectively, while the costs of concentrates increased by Rs 0.48 cow^{-1} d^{-1} in the paddy straw system. Net returns to investments in straw treatment were positive for UTPS at Rs 2.8 cow^{-1} d^{-1}, but negative for UTWS under rainfed conditions.

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Table 5. Results from on-farm trials with urea-treated cereal straws, Gujarat.

	Urea-treated paddy straw (UTPS)	Urea-treated wheat straw (UTWS)
Number of cows	24	11
	milk yield (kg cow^{-1} d^{-1})	milk yield (kg cow^{-1} d^{-1})
Period 1 (P1)	9.3	8.3
Period 2 (P2)	9.7	9.2
Period 3 (P3)	8.2	9.1
D1= P2–P1	0.4	0.9
D2 = P2–(P1+P3)/2	1.0	0.5

Farmers' reactions to the urea-treatment technology were mixed. Nearly all farmers in the paddy straw trial judged the treated product to be of appropriate colour (yellow to brown-yellow), but they also noted a strong ammonia smell. Fourteen of the 24 farmers using UTPS and 10 of the 11 farmers using UTWS recorded an increase in milk production. Nine of the UTPS farmers and 7 of the UTWS farmers perceived a positive impact on animal health (evidenced by a smooth, shiny hair coat). Four UTPS farmers and six UTWS farmers felt that treatment reduced straw wastage. Eighteen of the UTPS farmers and all UTWS farmers reported manure to be loose or pasty after feeding treated straws, complicating manure collection and dung cake preparation. Six of the UTPS farmers reported manure to be 'hard'.

Overall, 14 of the UTPS farmers, all on irrigated farms in Surat and Valsad, and 10 of the UTWS farmers reported that they would consider using treated straw in the future, while it was evident that farmers were eager to join the urea-treatment trial. Despite this initial enthusiasm, and the indication of possible future adoption, few farmers continued for more than a year, suggesting that the urea-treatment technology is only suitable when straw is abundantly available and other feeds, especially green fodder are scarce, as also reported by Schiere and Nell (1993).

Phase III: Area-based participatory field experimentation at watershed level

Case IIIa Focused approach within a watershed for increasing crop (soybean) yields

One of the conclusions drawn from the participatory approach was that more attention needed to be paid to non-livestock activities. A typical example is that of soybean production in Lalatora watershed, a micro-watershed in the northwest corner of Vidisha district in Madhya Pradesh (Chapter 1, Figure 2). In Madhya Pradesh, three agro-ecological zones (7, 8 and 9) of the central plateau and hills region of India (Ghosh, 1991) can be distinguished. This is the catchment area of four major Indian rivers, i.e., Yamuna, Ganga, Narmada and Tapi. Average annual rainfall is 1000 mm and temperatures range from 10 °C in winter to 45 °C in summer. Soils of the area range from medium black to red.

Major activities carried out in the Lalatora region were water harvesting, soil conservation, improving vegetative cover, livestock breeding and community empowerment, with participatory approaches and support of the government. Use of PRAs and soil analyses in the soybean-based farming systems showed that:

- soybean yields were low, ranging from 900 to 1200 kg ha^{-1}; soils were deficient in boron and sulphur; waterlogging prevailed; erratic rainfall created risks of insufficient soil moisture; last but not least, price fluctuations affected income of the farmers.

Based on theses observations a group of scientists, farmers and field staff selected location-specific interventions to improve soybean yields:

- Provision of critical inputs, i.e., micronutrients: (a) boron as Borax @ 10 kg ha^{-1}, (b) sulphur as gypsum @ 200 kg ha^{-1}, and (c) a combination of both;
- Broad Beds and Furrows (BBF): 1.5 meter broad beds and 30 cm wide furrows prepared with a tractor-drawn implement;
- Introduction of short-duration soybean (JS335);
- Seed treatment (with rhizobium/phosphate soluble culture to enhance nutrition and thirum for disease control);
- Water and soil conservation measures (farm ponds, field bunds, percolation tanks, check dams, gully plugs, waterways).

Medium and small farmers, interested to participate in the trials, were selected for the OFTs. Plot sizes varied from 0.15 to 0.25 ha and all farmers involved in the trials were trained in recommended practices and record keeping. There was no change in other agronomic practices, such as application of manure, fertilizer, sowing date, seed rate, harvesting, and use of pesticides on control plots. The following OFTs, managed by farmers and monitored by scientists, were carried out in soybean and wheat in 2001: use of the short duration variety (JS335), micronutrient trials using boron (B) and sulphur (S). Trained enumerators collected the production records of the trials with neighbouring farms as control. Seeds and other inputs were supplied at subsidized rates, and field bunds, farm ponds, check dams, waterways, gully plugs and percolation tanks were constructed by the village as part of water and soil conservation activities. Mean production data were calculated, cost-benefit analyses performed and farmers' perceptions recorded.

All three interventions of improved practices, micronutrient application (Table 6) and broad beds/furrows performed better than the control plots with traditional cultivation practices. The combination of boron and sulphur gave slightly higher yields than either boron (B) or sulphur (S) alone.

The economic analysis showed that the differences among the treatments are negligible for the combination of wheat and soybean. Introduction of the new variety and seed treatment were most appreciated by all farmers, followed by application of micronutrients (Table 7).

Case IIIb Soil and water conservation

Most interventions for soil and water conservation in Lalatora watershed were only partly adopted by the farmers (Table 8). Technical constraints (layout and design) and costs were the major reasons for non-adoption.

Table 6. Effect of micro-nutrient applications on soybean and wheat yields in on-farm trials in Lalatora watershed.

	Grain yield (t ha^{-1})				
	Soybean	Wheat	Soybean + Wheat	Net Benefit (Rs)	Cost-benefit ratio
B (1 kg ha^{-1}) (n=12)	1.73	3.74	5.47	26609	1:1.87
S (30 kg ha^{-1}) (n=12)	1.74	3.5	5.24	25955	1:1.85
B + S (n=12)	1.77	3.6	5.37	26454	1:1.82
Control (n=12)	1.40	2.7	4.10	17763	1:1.29

Table 7. Preference for technologies by farmers from Lalatora watershed using scoring.

Rank	Number of farmers favouring the practice	Technology intervention N= 30	Perceptions
1	30 (100%)	Short duration variety	High yields and responding to simple technologies; being aggressively traded Lower seed rate, responding strongly to additives
1	30 (100%)	Use of thirum	Seed can be stored longer Enhanced germination
1	30 (100%)	Use of bio-fertilizer	Very cost-effective User-friendly
2	25 (83%)	Mixed cropping	High income User-friendly
2	25 (83%)	Micro-nutrient application	Soil testing was new Combination of B+S is good Little support, higher benefit User-friendly
3	20 (67%)	New crop introduction	Blends easily with current practice at nominal extra costs.
4	8 (27%)	Reduced tillage	Have reservations about yields, do not want to risk larger area
5	6 (20%)	Broad Bed Furrow (BBF)	More lines of plants can be accommodated on bed Would like to change the planter accordingly The furrow walls support other crops Availability of implements is major constraint

Table 8. Adoption of soil and water conservation (SWC) measures (%; n = 45) in Lalatore watershed (source: Patil *et al*., 2002)

SWC measure	Adoption rate			Reason for non-adoption			
	None	Partially	Fully	Ignorance	Technical constraints	Expensive	Incon-venient
Land-levelling	2	91	7	NR	44	47	9
Waterway	9	82	9	NR	44	56	NR
Farm pond	33	51	16	NR	47	53	NR
Deep ploughing	4	91	4	11	45	44	NR

NR = No response.

The most important requirement for avoiding waterlogging in the rainy season is an adequate drainage system, provided by construction of a waterway. Although 82% of the respondents categorize adoption as ‘partial’, this seems to be an over-estimate, as a recent study has shown that waterlogging is still a major problem and that current drainage facilities are unsatisfactory (Vadivelu *et al*., 2001). Reasons for non-adoption include lack of technical knowledge and the high costs. Our hypothesis is that the major constraint is the perceived high costs, which the farmers are not willing or able to invest. Hence, to tackle the waterlogging problem, a programme should be designed that combines sufficient subsidies with a reasonable contribution from the farmers as an incentive for initiation of collective action.

Case IIIc Watershed development in Saurashtra, Gujarat

Frequent droughts and scarcity of drinking water in Saurashtra region triggered watershed development initiatives by the government. In fact, water had become a political tool in the caste-ridden hierarchy of the Saurashtra social fabric. This watershed programme effectively halted what was earlier an annual ‘ritual’ of deserting the drought-prone villages in Saurashtra region (Zones 6 and 7, Chapter 2). The programme objectives were:

- To develop wastelands/degraded lands, drought-prone and desert areas;
- To promote overall economic development for improvement of the socio-economic conditions of resource-poor and disadvantaged groups in the programme areas;
- To mitigate the adverse effects of extreme climatic conditions, such as drought and desertification on crops and the human and livestock populations;
- To restore the ‘ecological balance’ by harnessing, conserving and developing natural resources (i.e., land, water, vegetative cover).

In the mid-1990s, BAIF initiated watershed development programmes in 136 micro-watersheds (68,000 ha) in eight districts in Gujarat through different soil and water conservation activities, comprising surface and groundwater harvesting, management of common property resources (CPR), development of silvo-pastures, improving livestock and agronomic practices, dryland horticulture and grassland management. All activities from planning to implementation were based on community participation. Community empowerment, equity, including the landless, women empowerment and sharing of benefits of the created assets were key issues for the village-level watershed development committees, selected by the villagers.

Assuming that people's participation is the key to success, meetings were held in small groups and at village level to create awareness about the proposed development programme. Field officers tried to convince the farmers of the benefits of watershed development, such as improved soil fertility and increased availability of water, resulting in higher crop yields, increased feed resources and livestock improvement through breeding and vaccinations, safe drinking water, increased employment opportunities and ultimately socio-economic progress of the community. Audio-visual shows and visits to successful watershed programmes were also arranged to motivate the community to participate in the programme.

Realizing the importance of adequate response in the initial stages, the programme started with some attractive activities, such as providing drinking water facilities, building schools, roads, and community centres, all to benefit the entire community. To promote community participation, Village Watershed Committees were established and registered as societies under the Trust Act 1950, and these contributed in kind (labour) or cash up to 10 to 50% of the cost of the activities, depending on the capacity of the farmers. Their involvement created a feeling of ownership and self-confidence among the members that were actively involved and monitored the activities.

Khet Talawadi is a local term for the farm ponds that were built on farms where under natural conditions rain water drained out; like the '*kamdhenu*' it reflects a holistic notion. After the first rains, the farm ponds were completely filled, immediately recharging the wells. Despite deficient rainfall, water levels in the wells were maintained for longer periods. Water availability in the villages thus was higher, reducing the problem of drinking water. Moreover, farmers could cultivate a rabi (winter) crop. Also surrounding farms benefited from recharging of the well. As a result, cropping intensity strongly increased (by 19–24%) and crop yields increased by 20 to 80% (Table 9), also resulting in increased feed resource availability, reflected in increased numbers of livestock and milk production in some villages.

The consequence of the watershed development programme was greater awareness of the communities about the possibilities for improvements in agriculture through soil

Table 9. Level of water table in open wells and mean crop yields before and after watershed development in the year 2000 (Anonymous, 2000f).

Characteristics	Before			After		
	Monsoon	Winter	Summer	Monsoon	Winter	Summer
Water level in wells (m)	6	4.5	0.6	10.5	8.4	1.5
Crop yield (kg/ha)						
Cotton	560			880		
Groundnut	1000			1400		
Wheat		1000			2800	
Pulses	400	400		600	840	

and water conservation, and improved crop and animal husbandry due to increased in cropping intensity and availability of crop residues and empowerment of the community.

Discussion

On-farm experimentation is an important component of participatory approaches. A guiding principle in participatory approaches is that farmers engage in their own research (Okali *et al.*, 1994; Cornwall and Jewkes, 1995). The purpose of presenting the various ‘experiments’ in this chapter was to share the experiences of BAIF in the different approaches and methods used in on-farm experimentation in the last three decades of development work.

One of the dynamic aspects is the evolution of the communication systems. As illustrated in Case I, oral feedback from farmers and extension workers helped to develop alternatives for modification of fodder packages, to fit in the top-down application of AI to match the local conditions. Subsequently, these meetings were replaced by telephone and recently by mobile networks in rural areas. In Cases II and III, prior to the design phase of the trials, several meetings were held between scientists, extension workers and farmers on availability and costs of local materials, and types of farms and cows to be included in the trials. Based on these meetings, strategies for interventions such as supplementation in feeding, improvements in crop husbandry and/or water and soil conservation were developed. In supplementation, gotar, rice bran, urea, and leucaena and urea-treated paddy and wheat straw were selected. Concurrently, farmers were trained in feeding of the supplements and using local measuring devices. Both on-farm feeding trials illustrated the positive effects of supplementation on milk yield under field conditions, although supplementation with gotar, rice bran and urea was more effective than with rice bran and leucaena, while treated straw was marginally effective. Milk production increased when cows received supplementation, whereas there was a gradual decrease in milk yield of cows in control groups, due to the normal advancement of the lactation stage. Supplementation thus stimulates milk production, but in the 'field situation' many other factors influence milk production. In on-farm trials, groups of farms and animals are not homogeneous, as reflected in the case studies discussed, in the large standard deviations in feed supply and responses in milk yield. Our results would suggest carry-over effects of supplementation in the post-supplementation period. In our cost-benefit calculations, supplementation with gotar, rice bran and urea was more beneficial than with rice bran and leucaena. Treated straw was non-remunerative except in irrigated conditions, where farmers also feed extra concentrates. The net returns to investment in urea-treated paddy straw feeding were marginally positive but negative in case of urea-treated wheat straw under rainfed conditions. The participating farmers recognized the positive effect of supplementation in terms of milk yield and improved health status, and thus tended to reduce commercial concentrate and green forage supply in the supplementation phase. For experimental purposes, leucaena leaf meal was used in Trial II; in practice, farmers will feed leucaena leaves. As in general farm households have excess labour, the labour-intensive practice of collecting leaves is not an obstacle, so opportunity costs of leucaena leaves are small, but a major constraint is that they are not available year-round.

Smallholder farming systems are very much resource-driven (Udo and Cornelissen, 1998). So, it is essential to match interventions to the scarce resources available. Farmers perceived the supplementation strategies as useful, because they had the advantages of simplicity, local availability of inputs, clear results and low cost involved in adoption. Farmers cultivating pigeon pea, with access to leucaena leaves continued to feed gotar and leucaena leaves, however, they were more reluctant to feeding urea. Hence, despite the reduction in wastage of straw, higher intake and improvement in health, the urea treatment did not succeed. In spite of initial curiosity and enthusiasm, the limited availability of straw in rain-fed conditions and availability of labour are the factors adversely affecting adoption. Women did most of the work related to feeding and milking of the cows. Training of and demonstration to both husband and wife helped in acceptation of the supplementation strategies, despite initial reservations, in particular about feeding of urea.

The case study on soybean-based farming clearly illustrated the benefits of the introduction of a new variety and micronutrients in nutrient-deficient soils. Identification of the micronutrient-deficiency was crucial in planning this OFT and has triggered adoption by farmers. This was evident from the demand for seeds and micronutrients by neighbouring farmers from the area. That led to formation of a *seed bank*, organized by a group of farmers as a SHG (Self Help Group) to make seeds and other inputs available to large numbers of farmers (more than 2500) in the area. In Case III, dealing with soil and water conservation, lack of knowledge and the costs of interventions were constraints in adoption.

In general, the complexity of the field trials under different farm situations and the status of the animals make it difficult to select homogeneous groups of animals or farms in large numbers at one location. Constraints of labour availability, enumerators, money and logistic support are some of the additional bottlenecks in conducting on-farm trials. Researchers have to select the best option from '*with and without*' (which requires large numbers of animals and substantial support), or '*before and after*' (requiring less animals and support), which can save labour, time and money.

It can be concluded that the trials were effective in demonstrating to farmers the milk yield increases due to supplementation and the yield increase due to application of micronutrients. In general, on-farm trials can help in exchanging information between scientists and resource-poor farmers, and to stimulate acceptance of technologies by farmers. Use of local resources, small changes in the routine practices of the farm, simplicity, ample availability and accessibility of inputs and tangible results, are conditions that facilitate technology adoption by farmers.

Successes and failures in technology interventions are dependent on farmers' needs, their decisions in the context of the farm as a whole, their resources and accessibility to knowledge and services. Researchers and extension workers are more focused on the consequences of specific interventions, often ignoring effect(s) on (an)other subsystem(s), interconnected within the farm context. When technologies fitted into the functioning of the farm as a whole, their acceptance level increased, as illustrated in the case of area-based interventions. Similarly, in the forage promotion activity where seed packages were supplied in the rainy season, it was only later realized that farmers in the rainy season had other priorities, as ample natural greens were available during that season.

Hence, in technology transfer and adoption we cannot look at effects in isolation as an intervention in one component of the farm may have effects on other farm components.

CHAPTER 7

Dynamics in agricultural R&D for rural development: Cases from India

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Summary

Agricultural R&D for rural development of past decades has seen a variety of development priorities and approaches that disappear and re-appear, each with its own paradigms. For example, both temperate and tropical countries after WWII first stressed the need to win the war against hunger. This was done with considerable success, but trade-offs occurred, and priorities changed. Concerns about balanced rural development overtook concerns about food production, and notions on eco-system values started to accompany or even replace the earlier emphasis on primary production. Indeed, the earlier single focus on grain yield shifted to issues of regional attention for watershed management, and even to global concerns on topics like biodiversity, gender issues and CO_2 emissions. In that dynamic process, the top-down and grass-root approaches continue to replace each other while reductionist approaches alternate with more holistic ones, whether at farm or other levels. This chapter reviews a set of these fluctuations as illustrated in the work of BAIF, an Indian NGO that grew from Gandhian roots into a large development organization. These experiences are set against similar ones from the international scene and from industrialized countries, along with factors that influence the changes, and suggesting that agricultural R&D systems behave as complex adaptive systems with their own dynamics and associated paradigm shifts.

Introduction

Agricultural research and development (R&D) in both temperate and so-called developing countries immediately after World War II stressed the need to win the war against hunger (Stakman *et al.*, 1962; Van Keulen, 2006). That emphasis itself followed concerns about post-war famines that had taken place due to political uncertainty during wartime, droughts, floods, and/or bad record keeping and management of food-stocks (Sen, 1981; Drèze and Sen, 1989). The war against hunger was successful, e.g., it resulted in spectacular increases in crop yields during the Green Revolution in the 1960s and 1970s, at least partly due to the efforts of the Consultative Group on International Agricultural Research (CGIAR). This Green Revolution finds a parallel in the so-called white revolution for livestock of the more recent decades (Tables 1 and 2) and in spite of their differences, both rely largely on use of new varieties and increased use of inputs (Delgado *et al.*, 1999; Van Keulen, 2006). However, each victory seems to create new problems, the so-called trade-offs, such as social change, loss of biodiversity, pollution of natural resources and/or exhaustion of aquifers (Carson, 1962; Conway and Barbier, 1990; Schiere and Van Keulen, 1999). Consequently, R&D priorities continuously shift, associated with shifts in approach and/or paradigm. The rather linear and top-down approach of the Green Revolution was successful initially, through adoption in the more well-endowed regions, but more tailor-made solutions needed to be found through participatory approaches, as development shifted to more variable and generally more resource-poor regions (Conway and Barbier, 1990). Indeed, the focus on components worked well in the first years of the Green Revolution, but subsequent trade-offs triggered interest in a wide variety of more participatory approaches that can be summarized under the term Farming System Research (Simmonds, 1986; Merryl Sands, 1986; Fresco *et al.*, 1992). Unless indicated otherwise, this chapter uses the acronym FSR&E (Farming Systems Research and Extension), but FSR in general does offer a larger scope of methods than FSR&E in the narrow sense, of which the details are described by for example Shaner *et al.* (1982) and Collinson (2000). The main steps in FSR&E include characterization of the current situation, identification of the major issues for action, search for possible solutions, field testing and dissemination of the results. We argue that system dynamics lead to changes in priorities and they determine the usefulness of approaches and associated paradigms. In other words, neither technologies nor methodologies are useful across the board, but their usefulness depends on the context, as determined by space and time, and on the perceptions of the observer.

This chapter first reviews a set of such changes in approaches due to system dynamics in the work of the BAIF Development Research Foundation (BAIF), an Indian NGO where three of the authors spent many working years. That NGO developed

Table 1. Crop yields and associated characteristics in India during the Green and White Revolutions.

	Food grain yield (Mg ha^{-1})	Area under food grains (Mha)	Irrigated area (Mha)	Use of fertilizer (Tg)[1]	Milk production (Tg)	Concentrate feed (grains; cakes; bran; chuni) (Tg)
1950	0.52	97.3	No data	0.07	17	No data
1960	0.71	115.6	24.16	0.29	20	No data
1970	0.87	124.3	31.10	2.17	No data	No data
1980	1.02	126.7	38.81	5.52	31.6	No data
1990	1.38	127.8	47.43	12.55	53.6	28.6
2000	1.62	121.1	54.68	16.70	81.4	35.1

Sources: Department of Agriculture and Cooperation, Ministry of Agriculture, New Delhi; www.agricoop.nic.in; FAOSTAT, 2006.

[1] Tg = 10^{12} g.

from Gandhian roots with a holistic view on rural development into a large development organization, with its own agricultural R&D set up, including research stations, bull station, bull mother farms and laboratories. This development pathway is set in the context of similar pathways from industrialized countries such as The Netherlands, where other authors worked for a large part of their professional life. To better illustrate the dynamics, where appropriate, examples have been derived also from other countries in both poor and affluent conditions.

Early progress in Indian rural development, the case of BAIF

In the 1960s, India experienced both famines and the large yield increases of the Green Revolution, a stark contrast within one decade. Somewhat associated, but unrelated with that change was the fact that many young Indian scientists went to countries of the West and the East blocks to be trained in modern technology, often using reductionist methods to increase grain or animal yield. In the midst if all these changes, in the village Uruli Kanchan, near Pune (Western India) worked in the 1950s, Manibhai Desai, a former freedom fighter and follower of Ghandi, in rural conditions to uplift the rural poor (Upadhyay, 1991; Howard, 1993). Manibhai lived among villagers, working on the use of traditional medicine to cure the sick, as part of a more comprehensive village development programme. He noticed the central role of the cow in rural life of India, This cow is called '*kamdhenu*', a term that in our view represents a holistic concept in which the cow embodies a combination of many functions, as mother, producer of milk and even meat for some lower castes, young animals, dung,

Table 2. Major developments over the last half century, for BAIF, India, international and Dutch agriculture and agricultural R&D.

Time period	India	BAIF	International CG/Ford/Rockefeller	The Netherlands metaphor for W. Europe
1950/60	Recently independent famines; research system still very much colonial	Embryonic stage, Manibhai lived in village, start of nature cure ahram	Fighting hunger Establishment CGIAR	Recovery from war; many agricultural R&D workers hail from farms, assuring holistic approach in R&D, gradual shift to reductionism, treaty of Rome (Common Agricultural Policy of European Community)
1960/70	Yield increases through reductionist work and adopting many of CGIAR successes	Health care Community development Rather holistic approach	Silent Spring in USA; early victory Green Revolution; reductionist work; first trade-offs, early start FSR	Mansholt 'industrializes' farming; large-scale mechanization; exit from agriculture; shift to specialized farming, more reductionism
1970/80	Euphoria on Green Revolution in crops; first trade-offs apparent, early FSR	Establishment reductionist lab's; first large- scale cross breeding of cattle	Return to system approaches; emergence of several types FSR; establishment FSR Departments in IARCs	Victory 'modern' farming; early reductionist *and* holistic system work C.T. de Wit; first signals of negative environmental impact (Henkens)
1980/90	More balanced approach, FSR mainly in crops; gradual levelling of yield increases; early shift to export crops	Large scale cross-breeding of cattle; first signs of difficulty in across the board success; early notions on use of FSR	Greater emphasis on FSR; still focus on equilibrium thought Sense of crisis to keep control on world food production	First crisis 'modern farming' especially in livestock, mainly reductionist work to mitigate problems; start research on 'integrated' Farming Systems (OBS); milk quota system; first manure legislation; 'license to produce'; establishment De Marke, prototyping dairy farming and the environment; Farming with a Future – prototyping arable and outdoor vegetable farming
1990/2000	Integrated natural resources management, Integrated pest and nutrient management, WTO	Emphasis FSR-related work, from animals/crops to communities and watersheds	Publication Behnke *et al.* (1995) on non-equilibrium thinking; Eco-regional approach; Greenhouse effect and biodiversity; Integrated Natural Resource Management; Integrated Pest Management; Site-Specific Nutrient Management, establishment of livestock and environment initiative (FAO, World Bank)	Shift to nature; early start of FSR-related methods, prototyping, initiatives and work on farming related activity such as agro-tourism and value addition

draught and a source of savings and pride (Harris, 1967). In modern system terminology, this '*kamdhenu*' notion could be considered to represent 'multi-functionality', but we venture to think that in India at that time the cow was more seen as a whole, and not so much as the sum-total of different functions implied in 'multi-functionality'. Manibhai himself was rooted in this holistic thought culture, but was trained as a physicist in the reductionist tradition. During his village life, he started to study the cow, to see how she functioned, what she ate, how she reproduced, what her illnesses were, among others through dissecting animals against the rules of even his own caste. In other words, he started a process of reductionist analysis. In this process, he noticed the problems of individual people with their animals, and figured that improved breeds could help to enhance the chances of the rural poor. In practice that meant replacing local cows of low milk yield (approximately 600 kg in 240 days) with crossbred cows yielding approximately 2,100 kg in 300 days (Patil and Udo, 1997a, b; Anonymous, 1997).

Manibhai's overall work in community development was the start of a large NGO, the Bharatiya Agro Industries Foundation (BAIF) later renamed to BAIF Development Research Foundation. BAIF focused on identification and use of innovative technologies for rural development, among others in animal husbandry, reforestation, seed production, preparation of medicine and vaccines. Slowly but surely, the cow became focus of R&D, rather than a means to improve rural life. Reductionist science and approaches resulted in establishment of breeding centres, complete with bull stations, milk-recording, use of artificial insemination (AI), and feeding trials 'on station' rather than 'in the field' (Rangnekar, 1989; Mangurkar, 1990). The Indian Government, impressed by the initial success of the approach, financed the NGO to apply such an approach at a larger scale. Gradually however, constraints were encountered, as in efforts elsewhere to introduce the Green Revolution. Farmers and development officers working under different conditions gradually realized that standard approaches (both in terms of goals and methods) were not applicable everywhere, that tailor-made approaches were needed, and that farmers are specialists in their own right. This change in attitude was spearheaded by publications such as those from Chambers (1997) and Haverkort *et al.* (1991). Indeed, the early approaches were successful in the place(s) where they had been developed, but success was far less certain as the location (and thus the bio-physical and/or socio-economic conditions) changed (Conway and Barbier, 1990). We suggest that where interventions were successful, the local context changed and as a result, BAIF had to adapt its methods, also because it extended its programmes into farming systems that differed from the early ones (Rangnekar, 1993; Gahlot *et al.*, 1993). The early mix of participatory approaches and reductionist thinking of Manibhai Desai was replaced by top-down and target-oriented reductionist thinking of new staff, where such issues as the number of inseminations became important targets. Incidentally, the top-down approach fitted the attitude of traditional Indian farmers that were accustomed and prepared to take command from higher-up in the hierarchy, and it was the predominant way of thinking in traditional Indian R&D for agriculture. Desai originally started at the village level by implicitly using notions that later would become part of the FSR&E-methodology. To Desai, these participatory explorations came almost naturally as he lived in the local community, combining them effectively with the more reductionist approaches of his physics background (Chapter 1). Such an implicit tendency to participatory exploration can also be recognized in the work of for example livestock officers at the start of the 20th century in the Dutch East Indies, to whom FSR&E also came almost naturally, since they lived in the communities. Lack of transport and other communication facilities resulted in their participation in long evening chats with the local community (Schiere, 1995 quoting P. Hoekstra, Dept. Tropical Animal Production, Wageningen Agric. Univ., pers. comm., 1994). For the Indian situation, as targets were implied in government financing, the BAIF programmes shifted to a top-down mode, in which veterinarians were hired for livestock work and agronomists for work with crops. Interestingly, this tendency to specialization was recognized already 150 years ago in discussions by German agriculturists on whether one should accept a distinction between production scientists and economists (Nou, 1967). In addition, in the same process of scaling up, BAIF moved to the use of administratively designed extensive (baseline) surveys to replace the informal chats by Manibhai and early co-workers (Chapters 3 and 4). Furthermore, in the objectivist tradition, it was assumed that a success in one place could be extrapolated to other places. The top-down, specialized, uniformly oriented and bureaucratic approach was also almost forced on BAIF by the expansion of its organization, through funding by local (private and Government) and foreign sources combined with an objectivist mindset. However, BAIf soon discovered that large formal surveys and data collection systems were unwieldy, slow and labour-intensive, so it started to increasingly use the participatory rural appraisals and other tools from FSR&E (Rangnekar *et al.*, 1993a). This modification completed one cycle, i.e., BAIF had moved from Manibhai's informal and often qualitative information collection via large-scale and quantitative surveys, back (or forward!) to the informal information collection methods of what then started to be known as FSR&E. The change was brought about through a combination of ideas from outside the country, and local scientists that followed the changing realities on the ground in India.

International R&D for agriculture associated with Farming Systems Research

The international rural development community, spearheaded by the International

Agricultural Research Centres of the CGIAR started to realize already in the late 1960s that originally successful concepts, methods and tools cannot be successfully applied always and everywhere (Conway and Barbier, 1990; Collinson, 2000; Van Keulen, 2006). Within the CGIAR it was realized that in some areas the means had become goals, i.e., food production as a means for rural development had become a target to attain food security. Production of food grains and milk was guided by the economic value of the commodity, rather than by its impact on the community, a development similar to what happened to BAIF‘s focus on the number of inseminations as a target.

Strictly speaking, also this CGIAR attention for farming system approaches was a re-emergence of more participatory approaches that had been around in pre-war colonial days (Fresco 1986; Schiere, 1995). Indeed, the (inter)national agricultural research community also had come around a full cycle, from attention to the (small) farm as a whole in pre-war times via the rather single focus on the commodity, to the farm and even the community level, similar to BAIF. Another typical change inherent in the adoption of farming systems research took place in use of underlying paradigms, slowly shifting from reductionist focus on parts to more holistic focus on the farm as a whole (Scoones, 1996; Schiere *et al.,* 2004a). Still another shift occurred in approach, i.e., towards greater attention for small farm development (Shaner *et al.,* 1982), possibly caused by the fact that rich farmers have less difficulty than resource-poor ones in adopting high input technologies. Indeed, FSR was probably not really needed to reach the well-off farmers who selected and managed their own technologies, based on the Green Revolution approaches. Remarkably, and ironically, this move to more holistic approaches with attention for the farm as integral system took off internationally at the very time that the ‘holistic and participatory’ Desai began to dissect cows into parts and to describe the different functions in individual traits and characteristics. If this shows anything, it is that an appropriate combination of the two approaches is required rather than a one-sided choice for either of the two. In fact, this need for integration is well recognized in for example step 3 of FSR&E (Chapter 1, pg. 16) which addresses identification of solutions (or on-the-shelf technologies). The objective of that step is to identify both, technologies for field testing at farm level as well as issues for further research in laboratories and experimental stations.

In this process of a *re*-search for more holistic and participatory methods, a variety of farming system research approaches began to emerge, as explained in Chapter 1. These different approaches were based on ecological and socio-economic notions, as well as on approaches from systems analysis in industry and business (Checkland, 1981; Shaner *et al*, 1982; Simmonds, 1986; Norman, 1994; Collinson, 2000). At first, many of these approaches tended to aim for better targeting and more successful transfer of on-the-shelf technologies developed by *on station research.* They still tended to first focus on exact (objectivist) definitions of the farm and/or the farm household as a unit, on exact relations between crops and animals and on extensive surveys to exactly understand the prevailing farming system(s) (Fresco *et al.*, 1992). A subsequent major paradigm change was, however, the realization that components should be analysed in relation to other components of the same unit and beyond, implying a shift in focus from plant or animal level to farm and higher levels. FSR and/or its methods and tools gained acceptance in agricultural R&D around the world, and its approaches have proven to be more than just hypes (Collinson, 2000). The approaches even started to gain momentum in affluent Western societies, some thirty years after their emergence in the CGIAR system, and some fifteen years after being (re)accepted, among others in India and at BAIF (Ison *et al.*, 1997; Schiere *et al.*, 1999; Langeveld and Röling, 2006). In addition, the focus on agriculture as a means to guarantee food security and as 'engine' for rural development also changed in the last decades. Donors shifted attention to issues of rural development, environmental impact, gender, livelihoods and eventually to global change (IPCC, 2001), CO_2-sequestration, HIV/AIDS and biodiversity (Conway, 1987; WCED, 1987; UN Millennium Project, 2005) Ultimately, the view of the international donor community on agricultural's role in rural development is strongly linked to multi-functionality, rather than to the single goal of producing commodities, a major paradigm shift indeed from post-war emphasis on food alone.

Changed approaches in BAIF, reasons for and against change

The basic approaches applied internationally in the various forms of farming systems research were (re)incorporated into BAIF thinking, with a cautious start in the mid-1980s, initiated by Hegde in work on agroforestry (Hegde, 2001) and by Rangnekar on participatory approaches and gender issues (Rangnekar *et al.*, 1993), supported by international and eventually also national programmes (Schiere *et al.*, 2000; Anonymous, 2005). The use of FSR was not always welcomed within BAIF, either because "we have always done participatory work, so what is new?" or expressed as "why should a veterinarian deal with trees and gender issues?" A rather innocent 'ignorance' about the potential of FSR was illustrated by an anecdote in the late 1990s, when a group of field officers visited a location in Gujarat where livestock breeding was not well appreciated by the local community. The situation was analysed with typical FSR tools such as problem trees and SWOTs, familiarizing the group with field issues they had not realized before, e.g., conflicting labour requirements and feed problems. This led one senior officer to remark that this was indeed a good approach to analyse problems. He also recalled that he had been taught these methods some ten years earlier during early PRA trainings organized by one of us (JBS). His answer to the question why he did not apply those methods in his daily practice of livestock officer was "*we thought those methods were to be used on crops about which we knew nothing, but not on livestock issues of which we thought we understood everything*".

The changing priorities within BAIF are reflected in the use of large surveys to monitor dissemination of cross-breeding technology (Patil and Udo, 1997a, b). Those are followed by the use of different modelling approaches to establish which type of technologies might be useful where, and for whom field testing of the technologies illustrated with a variety of cases with field experiments. This closed the circle, from intensive and qualitative observation of village conditions by Manibhai Desai via a focus on on-station trials, collection of quantitative data and formal surveys back (or forward) to participatory field work. Another cycle is that from the holistic notion of '*kamdhenu*' to details (milk yield) and production of the cow as a goal, via the second and third modelling approaches of Chapter 5 on the animal as part of the herd (Chapter 5, Case II) to the '*kamdhenu*' as a means for development in whole farm models (Chapter 5, Case III) and the Khet Talawadi in watershed development (Chapter 6, Case IIIc). Indeed, the focus of much of BAIF's recent agricultural R&D is again on community and watershed development. Within these activities, the cow plays a role in reforestation and saving schemes, but milk yield and cows *per se* are not the main focus anymore, an approach resembling the vision of Manibhai in the early 1980s. The basic lesson is that agricultural R&D needs a combination of different approaches.

The dynamics of R&D paradigms around the world

Globally, priorities, methods and approaches in agricultural R&D are in continuous movement (Rabbinge, 1997; Van Ittersum *et al*., 2004; Van den Ban and Samantha, 2006). Overall, the use of FSR-approaches is (re)appreciated in terms of their capacity to reorient existing programmes, as well as to affect R&D paradigms. FSR has enabled researchers and policy makers to establish new priorities, for example where livestock specialists recognize the need to understand cropping patterns and where agronomists start to pay attention to issues of community rather than only commodities. Indeed, FSR and the increased interaction between R&D and farming communities have also affected basic paradigms, e.g., away from focus on individual parts to equal attention for their interactions within the system, and thus its dynamics, here called a more holistic approach. This is evident where high individual milk yields of a cow may affect (an)other (re)productive performance characteristic(s) of the animal and/or the herd. And where optimum cow performance, determined by the specific combination of feed and breed depends on the cropping pattern, and/or priorities in watershed development. Last but not least, it implies that technology selection is 'niche-dependent', e.g., what may be good for one farm(er) may not be good for a farm(er) elsewhere in space and time.

At international level, appreciation of these notions started with the move to FSR in the CG-centres from plant and plot to farm level, especially for resource-poor farmers who had to live with variation, because they lack the means to correct differences in resource flows (Conway and Barbier, 1990). But also in so-called developed countries the concept started to gain ground, partly because 'the environment (society)' refused to accept the 'waste' generated by 'wealthy' farming practices (Henkens and Van Keulen, 2001), partly due to societal change caused by continuous upscaling of farming systems and/or exhausting resources. A typical case of the former took place in The Netherlands where it was part of an ongoing debate between groups with a more biophysical approach and with a socio-cultural focus (Röling, 1994; Leewis and Pyburn, 2004). The scientific differences between these two groups led to a combination of participatory, interactive and mathematical modelling approaches based on objectivists notion (Vereijken, 1997; Van Ittersum *et al*., 2004). The societal concerns also led to more socio-economic and constructivist approaches associated with groundbreaking work in Australia by Richard Bawden and associates (Campbell, 1996; Roberts and Coutts, 1997). Early use of FSR-methods in rural development programmes in Australia has also been reported by Ison *et al*. (1997), who picked up elements from FSR work in Africa (R. Ison, Open University, UK, pers. comm., 1999). The Australian work specifically included attention to paradigm changes, from traditional objectivist concepts associated with reductionist approaches to concepts of constructivism and continued learning. The shift from focus on parts to more holistic views occurs in both the so-called hard and soft sciences, where the first represent research on biophysical issues and the second pay particular attention to issues of mindsets, paradigms and socio-cultural behaviour (Schiere *et al.*, 2004a).

The shift to more holistic approaches involves in the first place increased attention for relations between parts and the associated system dynamics. A more holistic approach is *not* simply a shift from one spatial scale to another, e.g., where attention to animals or crops is replaced by attention to an individual farm. The shift from attention to farms as a whole to commodities (early 20th century in Europe, and in the European colonies and as late as 40 years ago by Manibhai), and back to more holistic thinking about 'commodities for communities' through FSR&E approaches is thus a common phenomenon. It appears in the work of the CGIAR, Indian agricultural research systems, in an NGO as BAIF and in The Netherlands as well as in the rest of Europe and the so-called developed world (Table 2).

Importantly, it appears that modelling replaces empirical testing as the scale of interventions increases from plot to farm or higher, and from short-term to long-term.

A shift to holistic approaches does not exclude empirical and reductionist work, but it includes and combines all those approaches. Last but not least, a shift to more holistic concepts implies attention to system dynamics as noted before. In the framework of this thesis it all implies that agricultural R&D can be considered as a complex adaptive system, showing adaptive behaviour (Gunderson and Holling, 2002). Incidentally, this cyclical behaviour is typical for 'Eastern' Hindu thought, as opposed to more goal-oriented thinking in the 'West'. The associated roles of farmers and extension workers also reflects similar dynamics as shown in Table 3, from top-down to more participatory approaches.

Final reflections and concluding comments

The notion of change (= dynamics) in agriculture and society, and of agricultural R&D as a complex adaptive system is not new, even if presented under different names at different times. The standard text on tropical farming systems by Ruthenberg (1980) focuses on static description of variation (= dynamics) of farming systems in space, but it treats, at the end of each chapter, dynamic concepts, i.e., the evolution of that particular system. Earlier, the 19th century location theory by Von Thünen described 'evolution' of farming systems as a function of their distance to the city. This was followed by work of people like Roscher, Krzymovski and Aereboe who introduced notions of 'Stufen' (=stages) in time, associated with the notion of the intensity theory

Table 3. Changed roles of researchers, extension workers and farmers as experienced by BAIF (based on discussions with BAIF staff).

Period	1970-1980	1980-1990	1990-2000
Explanation of farmers' non-adoption	Ignorance Farm level constraints Farmers perceptions	Farm level constraints Non-availability of inputs	Watershed level constraints Technology does not fit
Solution	Extension and aware ness raising	Remove farm level constraints	Change of process and context
Key extension activity	Training	Input supply	Facilitating farmers' participation
Socio-economic research	Understanding diffu sion and adoption of technology	Understanding adoption of technologies and farming systems	Enhancing farmers' competence and participation Understanding and chang ing professional behaviour
Predominant research method	Group discussions Informal feed back	Questionnaires and surveys Constraint analysis	Farming systems research Participatory research by and with farmers

(Nou, 1967; Krabbe, 1995), and even reflected in work of the mid-20th century (Rostov, 1961). Still earlier, agricultural economists like Malthus (1798) studied the evolution of farming systems and population pressure in time. More recently, Chayanov studied the variation in Russian farming systems as a function of family age and composition (Thorner *et al.*, 1966), but he also described a case of system change, as if predicting what happened in India over the past decades.

Still later, Schumpeter uses the term creative destruction (at least implying a Hindu notion when he describes the process of rise and fall of economic systems with interesting work on technological innovation (Schumpeter, 1954). As an interesting sideline even Malthus used the notion of creative destruction, when he wrote his famous essay on principles of political economy (Hodgson, 1996). The evolutionary approach is a clear departure from neo-classical economic thinking, where more static approaches are used, and it reflects the choice made by many system thinkers when they distinguish the 'being' (static) *versus* the 'becoming' concepts of our existence (Prigogine and Stengers, 1985). Also Boserup (1965), in her work on evolution of agricultural systems, introduced the concepts of induced innovation, illustrated with the example of higher population pressure leading to higher agricultural productivity. The tension between thinking in terms of linear (rather static) and non-linear (more dynamic) approaches is apparent in the work of Scoones (1996) and Behnke *et al.* (1995), who deal with concepts of 'non-equilibrium' thinking in the minds of farmers, particularly in unfavourable and uncertain climatic conditions. We suggest that both 'Western' *and* 'Eastern' reductionist thought and static concepts are in search of a new balance with 'Western' *and* 'Eastern' concepts of holistic and dynamic development.

Concluding, we like to highlight three major issues, in relation to our notion that agricultural R&D can be considered as a complex adaptive system, also called a learning system (Senge, 1990; Röling and Pretty, 1997). The first is the tension between the usefulness of reductionist approaches on the one hand (understanding the cow's parts, or methods to increase grain yield), and holistic approaches on the other (the cow and/or the grain crop or even the community as part of a larger system such as the farm or the watershed). Second, and implied in the former, is the importance of the context that determines the usefulness of a particular technology and/or R&D approach. It can be useful to use a linear top-down approach in adopting technologies such as Artificial Insemination or high-yielding varieties in certain farming systems, whereas their adoption may be counterproductive in others, or in the long term. Third, we noticed remarkable cyclical dynamics in agricultural R&D systems, running out of phase and at different rates between organizations and locations. Such dynamics appear to be reflected in larger-scale shifts of methods and paradigms, as illustrated in major fluctuations in thinking in 'scientific' methods from the time of the 'Western'

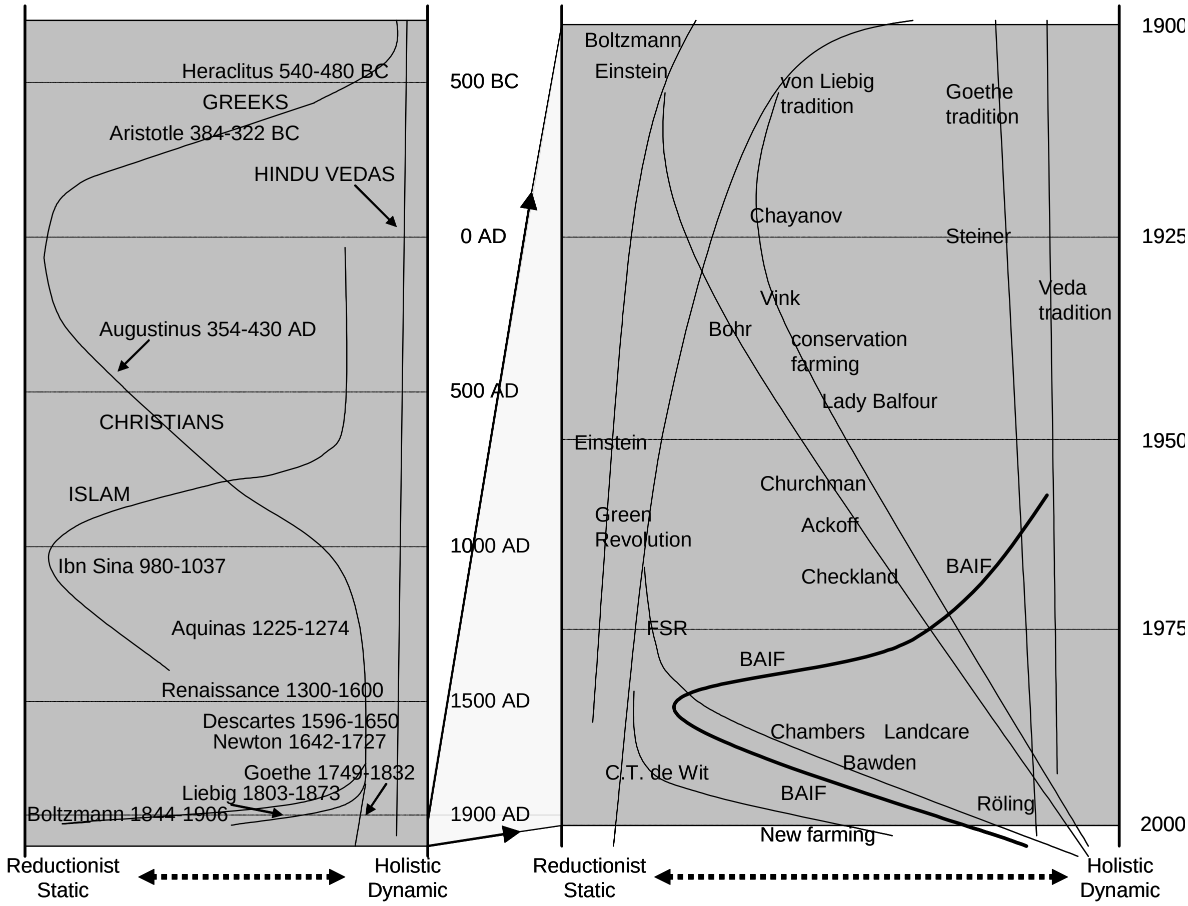

Figure 1. Sketch of dynamics in system thinking from 500 BC to 1900 AD (left) and for the 20th century (right). Differences such as between empiricism and rationalism are left out, and for topics / authors not referred to in this thesis see Gaarder (1996) on main trends in Greek-Christian traditions, Jackson (2000) on Churchman, Ackoff and Checkland; Pais (1982) for the Bolzmann-Einstein-Bohr traditions; Armstrong (1993) for Islamic, Parkes (1987) for Vedic traditions; and Conford (1988) for organic faming traditions.

Greeks and the eastern ‘Vedas’, the old Indian scriptures (Figure 1).

Accepting the concept of dynamics in agricultural R&D as a hypothesis, we have not further elaborated the theoretical arguments on why and how they reflect the properties of a complex adoptive system. In the context of this thesis, it is more relevant to identify which approach and which technology fits when and where. Using a broad brush method, a set of practical recommendations can be formulated, at least as a hypothesis for further work.

When a particular farming system is well understood, application of a top-down approach may be effective, especially for technologies that by their nature require external ‘interference’. In the Gujarat situation, that applies to the use of AI for crossbreeding or the introduction of high-yielding varieties of crops. Appropriateness of the technology should be plausible, based on *ex-ante* 'analyses', such as performed by Manibhai Desai in his informal chats, PRA, or quantitative modelling approaches as illustrated in Chapter 5.

Even if one takes the justified step to introduce a promising technology or management practice, one has to be prepared for follow up. As the environment continuously changes, no method can be applied forever and non-linearity is bound to show up. Use of crossbred animals may eventually be constrained by available feed resources; and use of high-yielding varieties may be limited by available water resources. In that sense, a 'negative' feedback should be taken seriously, and it can imply re-training of staff or re-organization of the institution, a major property of complex adaptive systems and learning systems (Senge, 1990).

Work at component scale has different characteristics, depending on for example whether it is feed or breed. Introduction of a new seed or breed may imply a considerable input from outside, but innovations such as modifying feeding or cropping patterns leave more room for farmers' participation.

A shift from component to higher scales implies a need for other approaches. It may require standard statistical tests to examine whether a technology such as feed or breed performs well under standard conditions at farm level. When applied at community or regional level in a variety of contexts the type of criteria starts to change, requiring (novel statistical methods and/or) well-developed participatory approaches, based on ranking of farmers or community preferences rather that experimental designs used at experimental stations. And testing of a new farming system or watershed management may in theory use standard statistical tests such as ANOVA, but those are simply not practical at such levels.

Last but not least, it appears common to slowly shift attention from animal and crop to other system scales and *vice versa*. That may be to lower scales, into feed, breed, vaccines, physiology or cellular level as happened in BAIF and CGIAR. It can also be to higher scales, such as the watershed or policy development as also occurred again in both organizations.

The dynamics of agricultural R&D require an open-minded and constructivist approach. *A-priori* selection of one and only one useful approach and/or technology should be avoided. Continuous attention is necessary for the choice of appropriate method, when and where and by whom. This chapter contributes food for thought in this respect.

CHAPTER 8

General discussion

General

This thesis deals with identification and testing of suitable technologies and methodologies for improving livestock production in the framework of rural development. It does so specifically by analysing the livestock development programmes implemented in Gujarat (India) by BAIF, a large NGO. The thesis discusses the use of participatory tools for constraint analysis, construction of an intervention matrix and simulation modelling to identify technologies in feed and breed, both by using *ex-ante* and *ex-post* analyses. It studies the role of crossbreeding and feeding technologies at farm and system level and discusses experiences in field experimentation against the background of the dynamics of agricultural research and development over the past three decades. It also highlights some cross-cutting issues on approach encountered in the development process.

One hypothesis in this work is that dairy farming can play a positive role in rural communities and that it is positioned to be a major growth area in the Indian agricultural sector. And indeed, it is likely that the vast population of bovines (288 million) in India has a major role to play in rural development and poverty alleviation (Thornton *et al*., 2002; Kruska *et al.*, 2003). For example, dairy production involves around 70 million farming households of which the majority are smallholder mixed crop-livestock farmers. Also in Gujarat dairying is an important secondary occupation for a majority of the farmers (85% of the rural population), and specifically for resource-poor small farmers (Chapter 2), for whom it does contribute substantially (30-50%) to family income (Chapters 3 and 4). State Governments and development agencies promote dairy farming as a means for self-employment and poverty alleviation, and many efforts are focused on increased milk production. Still, low yields abound, due to, among others, limited availability and poor quality of feeds, as well as genetic potential (Mangurkar, 1990; Patil and Udo, 1997a, b).

Another hypothesis implied in the first two research questions (Chapter 1), is that it is possible indeed to explicitly establish a set of useful technologies and approaches. In the course of the work reported in this thesis it became increasingly clear, however, that (a) dairying forms a part of the whole farm system and (b) systems are inherently dynamic. This observation in part answers the third research question, as it means that interventions at the animal level can imply changes elsewhere in the system, so that approaches/technologies identified as useful at one point in time and space may not be useful at another point. In addition, of course, changes are also imposed by outside factors like new technologies, global climate change and accession to WTO, to name a few of such processes.

The role of livestock in rural development and the possibilities and constraints for livestock development will be discussed below, following the chapters of this thesis, to more precisely answer *the questions formulated at the start of this research:*

- Which criteria can be used in selection of appropriate technologies for dairy farming systems in Gujarat?
- Which methodologies are suitable to promote adoption of these technologies at farm level?
- Are there any differences in methods of selection and adoption of a given technology in the farming systems that are being studied?

As answers to the questions posed in this study were pursued, the thesis also became a narrative on BAIF's livestock development work that uncovered more general aspects of BAIF as a learning organization. Development of this narrative benefited from the roughly 30 years involvement of the author in rural development by BAIF, and it also shows long-term changes in the organization, in development paradigms of its main financiers and of the environment in which it had to work.

BAIF and livestock development in India

Livestock development in India, the main tools and paradigms

The first and second chapters of this thesis describe the dynamics of livestock production over the past five decades in the general context of India, and of Gujarat in particular. Maps, transects and statistics are used to describe the numbers and distribution of livestock species, mainly following the approach that in Farming Systems Research & Extension (FSR&E) was elaborated by, for example, Shaner *et al*. (1982) more than two decades ago. It is shown that at the level of community and state it is possible to indeed estimate total numbers and perhaps the contribution of livestock to gross national product, but labour requirements and feeding calendars can only be given at such a level of generalization that the results become rather irrelevant for individual farmers. And for policy makers, the aspects of processing, marketing, export and poverty alleviation are more relevant than type of animal herd or farm. Some tools, such as maps and transects can be used at both, village and farm level, but the type of information shifts from general to farm-specific, at State level allowing only some rough guesstimates of what farmers might consider a 'useful' technology.

The first two chapters thus describe the use of Farming Systems Research, with emphasis on a particular form, referred to as FSR&E (Shaner *et al.*, 1982; Simmonds, 1986). That approach does use tools of participatory rural appraisals (PRAs), such as zoning, transects, maps, as mentioned above, with their particular emphasis on farm and community level. Based on constraint analysis and knowledge about local resources, a so-called intervention matrix was designed (Tables 1 and 2) that helped in selecting the technologies suitable for different niches (criteria), e.g., suitability of breeds and feeding technologies for specific agro-ecological zones and/or social groups. Such intervention matrixes were introduced into BAIF programmes among others through the work of the BIOCON project (De Boer *et al.*, 1994a; Schiere *et al.*, 2000). They use scoring by expert panels, including farmers, to indicate the likelihood of a given technology to be useful for a specific farming context.

Ex-post *evaluation with formal surveys*

The early work of BAIF's founder, Manibhai Desai, including informal discussions at

Table 1. An intervention matrix on breeding and feeding interventions in relation to the criteria- zones, breeds and social groups.

Intervention \ Criteria	Zone 1*	Zone 3**	Zone 6***	Tribal	Non-tribal
Breeding					
Crossbreeding	++++	++++	++++	++++	++++
Gir	-	-	++	-	++
Buffalo breeds	Surati	Surati, Murrha	Jafarabadi	Surati, Murrha	Murrha, Surati, Jafarabadi
Feeding					
Urea supplementation + rice bran + gotar	++	++	+	++	++
Leuceana leaves	++	++	-	++	++
Concentrates	+-	-	+	-	++
Urea-treated cereal straw + concentrate	++	+	-	++	++

* Irrigated mixed farming, strong market infrastructure;

** Rainfed mixed farming, strong market infrastructure;

*** Rainfed mixed farming, weak market infrastructure.

Zones refer Gujarat Plains and Hills region (to Chapter 2).

- least useful; + useful; ++++ more useful.

Table 2. An intervention matrix on feeding technologies suitable to breeds.

Intervention \ Breeds	Gir	Non-descript	Crossbreds
Urea supplementation + rice bran + gotar	++	++	++
Leuceana leaves	+	-	++
Concentrates	+	-	++
Urea treated cereal straw + concentrate	+	-	++

- least useful; + useful; ++ more useful.

community level and actual dissections of cows did help to identify the role of livestock and the use of a particular technology (crossbreeding with doorstep delivery of Artificial Insemination, AI) as stepping stones for rural development. Chapters 3 and 4 present the results of formal surveys to establish the impact of this technology. This surveying work was done as an *ex-post* analysis, i.e., the technology was introduced as a good guess, but it was evaluated after a few years. This work is part of Farming System Research *sensu latu*, but it is not as action-oriented as FSR&E, and it represents a form of FSR that Simmonds (1986) calls FSR *sensu strictu*.

An *ex-post* monitoring of the crossbreeding programme to evaluate the results in terms of production parameters, and its achievements helped to identify future directions and discussions with policy makers on future priorities (Chapters 3 and 4). It showed that the introduction of crossbreds has a major impact on smallholder mixed farming systems, irrespective of agro-climatic conditions and beneficial to both tribal and non-tribal farmers with access to markets. *Ex-ante* work reported in Chapter 5 confirms these results, also showing that crossbreeding for higher milk yields can be an important development option for resource-poor farmers, such as the landless and the tribal, depending on their access to the market.

The *ex-post* work, both formal, through surveys and informal, through discussions between farmers and field officers, gave feedback to re-orient scientists and extension workers. This was a basis for further refinement of breeding plans to improve production, for changes in interventions and in approach required to match the felt needs to incorporate local breeds and crossbred semen, arising from developments in time and space. However, the formal surveys are labour and time-consuming and they produce results long after the possible problems or successes of the technologies become apparent to farmers and development agents. Indeed, constant informal contact between AI technicians and farmers revealed problems and successes long before the formal surveys were even started. The informal contacts between the actors in the process, in the spirit of FSR&E, had already shown that feed problems, health issues and calf mortalities were the major points of attention, while the surveys worked on criteria as milk yield, and farm economics. The problem of method in this respect is, that formal surveys of FSR *sensu strictu* are slow, inflexible, time-consuming and costly. Such methods yield much quantitative information, but not necessarily of the right type, because context and questions change over time.

Identification of criteria such as breed, social group, and/or agro-ecological zone is relevant in selecting solutions to address farmers' problems, based on local resources, knowledge and farmers' priorities. These criteria may change independent of stage of development, or shifts in priorities and target groups. An example of such a change in criteria is the case of the poorest of the poor, who cannot maintain large ruminants, so that other options have to be considered, such as small ruminants or poultry, depending on skills, preference and/or capacity. Hence, in the criteria, different breeds of large ruminants should be replaced by other animal species, such as small ruminants or poultry. Access to the market and/or options for processing of fresh milk or by-products could be other criteria in deciding on whether or not to increase milk production.

Ex-ante *evaluation and use of modelling for breed and feed*

Two major drawbacks of *ex-post* analyses are duration and inflexibility on the one hand (if based on formal surveys), and the fact that a technology is chosen before it has been analysed for impact, on the other. One alternative to such *ex-post* analyses is the use of modelling, for which many different methods and tools are available (Thornton and Herrero, 2001), to establish beforehand the usefulness of one or more technologies. An *ex-ante* evaluation of usefulness of technology in this thesis takes the form of a qualitative discussion in 'expert panels' about the suitability of technology, as done in Chapter 2, e.g., with the use of an intervention matrix.

The three quantitative modelling methods used in Chapter 5 are different from each other in scope and approach, each with its own advantages and disadvantages. The first is a simple spreadsheet calculation, useful for short-term and straightforward technology assessment, in this case the economics of using concentrate supplementation for milk production. The results clearly show that distance from an urban centre, reflected in differential transport costs, is an important factor in deciding on the economic usefulness of this technology, based on marginal cost-benefit analysis. This is a 'replay' of the famous calculations by Von Thünen on his location theory some 150 years ago in Germany (Nou, 1967). It is confirmed by observations in other countries (Owango *et al.*, 1998). The second is a more comprehensive and complicated approach, i.e., the use of a herd dynamics model (Udo and Brouwer, 1993) that considers the effect of feeding practices on various biological and economic characteristics at animal and herd level, such as live weight gain, milk yield, herd growth, protein and energy balances and gross margins. The main use of this method is to select technologies on the basis of multiple criteria of breed and feed at animal and herd level. Results indicate that crossbreds are more remunerative for landless and tribal farmers than for small non-tribal farmers, findings that agree with studies reported in Chapters 3, 4 and 6. The feeding interventions are more effective for crossbred than for local cows in terms of production parameters, due to the limited genetic potential of local cows. The third method used for *ex-ante* analysis is linear programming, using a fairly simple approach with a small matrix that is run several times. It uses total farm income from a mixed farm as a characteristic to assess the usefulness of technological interventions in terms of feed, breed and cropping pattern, either separately or in combination. The results indicate a need to shift from animal to whole farm level, representing a paradigm shift from a reductionist focus on parts of the farm to the scale of the entire farm. This recognizes interconnectedness of crops and livestock systems within the whole farm (Patil *et al.*, 1993).

Quantitative modelling, as applied in Chapter 5, supports selection of a few best-fitting technologies for on-farm testing. It helped BAIF to identify the feeding technology most likely effective in overcoming the nutritional deficiencies of the animals. This method is thus useful in identifying suitable single or combined animal-oriented technologies (breed and feed) and crops at farm level. The results would suggest that total farm output is a more relevant characteristic than individual yields of animals or crops.

Field experimentation

An intermediate methodology for technology testing, between *ex-ante* and *ex-post,* is field testing of technology as popularized by, for example, Chambers *et al*. (1989), Scoones and Thompson (1994), and Okali *et al*. (1994). This type of approach does indicate a paradigm shift from the concept that research can provide top-down solutions, towards the concept of indigenous technical knowledge, i.e., the recognition that farmers themselves are active experimenters (Haverkort *et al*., 1991; Van der Ploeg and Long, 1994). Many forms of such field testing exist, particularly in phase 3 of FSR&E, and their use for a broad range of technologies is the subject of Chapter 6. The main approach in that chapter is to consider a wide range of experimental techniques as being part of field experimentation *sensu latu*. Part of these field experiments are so-called on-farm trials as advocated in FSR&E. These can be further distinguished into more formal on-farm research and more informal on-farm trials (Yazman *et al*., 1994), i.e., covering the range from scientist-designed /controlled to farmer-led on-farm trials (Mettrick, 1993). Other forms of field experimentation are less well-defined, e.g., the use of AI at farm level, as in BAIF's early work, similar to Simmonds (1986) distinction of specific forms of FSR within a much wider range of approaches in FSR *sensu latu*, or the work with different methods of erosion control and water harvesting in the watershed programmes of the later BAIF work. The chapter recognizes three phases in time, with associated paradigm shifts from reductionist to holistic thinking. These three phases in the field experimentation in 30 years field work by BAIF are:

- Rather top-down presentation of technologies such as crossbreeding and fodder production, to be evaluated informally in the course of the process, on criteria such as practicality, unexpected trade-offs (positive and/or negative), newly emerging problems and local relevance. They can also be evaluated on the basis of large formal surveys, as discussed in Chapters 3 and 4.
- Participatory selection, testing and modification of technology, illustrated with the use of feed supplements, urea treatment of straws and even improvements in crop production. Indeed, BAIF in some cases decided to engage in crop improvement programmes, despite its initial focus on AI and crossbreeding. That was an important step, because participatory work does imply that the development agent should be prepared to follow farmers' priorities. The methodology of crop improvement is not fundamentally different from work with animals, even if time and space scales may differ (Amir and Knipscheer, 1989; Schiere, 1995). In all cases, farmers' involvement is important in terms of record keeping, labour and management of trials and providing feedback on desired modifications to scientists and extension workers. Assessment, based on quantitative and qualitative analyses with respect to techno-economic and social criteria does lead to judgment of suitability and the possible need to modify the technology.
- Technologies shifting from animal and plant via herd and plot to farm level and beyond (e.g., watershed). Interestingly, the first part of such upscaling is also illustrated in the transition from Case I to II and III in Chapter 6. In that chapter, the third phase of field experimentation takes the development process one level higher, to the watershed. Analyses at that scale are also performed in international agricultural R&D, for example, in the IMGLP work of Roetter *et al*. (2000).

BAIF's own experience with field experimentation lies in methods such as top-down, participatory, demand-led or a mix of these, depending on context, i.e., the specific stage of development in time and space. The usefulness of such a mix is also emphasized by Heffernan (2005), who stressed demand-led processes are unlikely to be sufficiently innovative.

Differences between systems and dynamics in agricultural R&D

The broad conclusion that emerges from the first three sections of this thesis is that one cannot identify specific methods, tools, criteria and technologies that are universally useful. This is emphasized even further in Chapter 7 that discusses the long-term dynamics in the work of NGO's such as BAIF, in comparison to experiences in international agricultural R&D. Development priorities and approaches appear to change continuously, together with their own paradigms, thus exhibiting characteristics of complex adaptive systems and/or learning systems (Röling and Pretty, 1997; Gunderson and Holling, 2002).

It reflects a paradigmatic discussion on whether development is considered as a continuous process towards some kind of a final equilibrium (end situation), or as a series of steps in an 'endless' cycle of often repeating phases. In essence, this discussion is reflected in the concepts of equilibrium *vs* non-equilibrium thinking (Hodgson, 1996; Behnke *et al.*, 1995; Ragsdell and Wilby, 2001). In practical terms, this constant change is encountered when studying (inter)national agricultural R&D, where concerns on balanced rural development gained priority over concerns on food production, so that the focus shifted from grain and animal yields to attention for watershed development, gender and biodiversity, to name a few. The shift to more holistic and non-equilibrium approaches implies increased attention to relations between parts and their role in system dynamics. A shift to holistic approaches does not *exclude*, however, empirical and reductionist work; it includes and combines all those approaches. This provides an answer to the third question in this thesis, i.e., on whether there are differences in method of selection and application of given technologies in the farming systems that are being studied. First, however, we need to discuss a few remaining issues that have emerged in the course of the studies reported in this thesis.

Additional issues encountered during the work on this thesis

In the course of the research, some cross-cutting issues emerged from the various activities, over the long period covered in this thesis. Those issues deal with aspects of R&D objectives, priorities, paradigms and needs of various stakeholders that influence the success of development programmes over time. Some of the most relevant issues are discussed in this section.

Hierarchical levels and 'grid'

The work reported in Chapter 2 illustrates that national scale statistics do not reflect realities at farm household or field scale. In addition, the modelling experiments of Cases II and III in Chapter 5 show that an intervention at one place in the system has an effect somewhere else in that system, whether at higher or lower levels of system

Table 3. A modified SWOT analysis on the advantages and disadvantages of livestock on farm and regional level, performed by a group of extension workers from south Gujarat, 2002,

Farm level strengths (advantages)	Farm level weaknesses (disadvantages)
Employment	Inadequate feed resources
More income	Inadequate veterinary services
Regular income	Low milk price
Manure complementary to crop production	Limited water availability
Draught	Limited labour availability
More nutrition increases food security	High feed cost
Quality of life	
Status in society	
Security during crop failures	
Regional level opportunities (advantages)	**Regional level threats (disadvantages)**
Employment	Soil erosion
Rural industry	Pollution
Recycling agricultural waste	Limited feed resources
Enriching ecosystem and environment	Public health
Increased income (GDP)	Global competition
Value addition and export	Price policy
Empowering community	

hierarchy. Maximum farm production can require adjusted animal production; livestock production may add income at farm household level, but it can cause soil degradation at community or regional level (Table 3). This phenomenon plays a role in many situations: a regional fodder scarcity may not draw national attention, while a cyclone with local effects may draw (inter)national attention. As said before, transects and maps at national level have little or no meaning at local level. They can be made with different purposes in mind, for example for administrative reasons, rather than for agro-climatic work, or socio-economic purposes. The issue that national maps and priorities have limited or no relevance for local conditions always emerges in discussions about top-down and bottom-up approaches. It is apparent in the fact that the per capita availability (PCA) of milk in India is 230 g d^{-1} for the nation as a whole. However, Punjab State has a PCA of 950 g and Nagaland of only 80 g (Anonymous, 1997). National herd composition averages have no relevance at local level and regional level averages have no relevance at farm level; in small villages, farmers may own only one cow or they may send the young stock for rearing to other regions. Issues of 'grid' and hierarchy can be discussed in many ways, e.g., Klir (1991), Capra (1996), Ragsdell and Wilby (2001). But the essence is that the expectations of different stakeholders at different levels need to be recognized (cf. Lopez-Ridaura, 2005).

BAIF copes with this problem by integrating farm household-focused activities such as livestock development with area-based development programmes such as watershed development, but tensions between these levels do exist. The SWOT analysis (on Strengths, Weaknesses, Opportunities and Threats) of a BAIF programme as performed by the group of extension workers as shown in Table 3 is an example. It is a modified form of more conventional SWOTs, translating internal farm level strengths and weaknesses, and external opportunities and threats into advantages and disadvantages. The table illustrates how an advantage of livestock farming at farm level can be a disadvantage at regional level.

Interconnectedness of systems and relations among zones

The concept of interconnectedness implies that the systems are related in one way or another, and to different degrees. Indirectly, this is reflected in the issue of hierarchy in the previous sub-section, where an effect at one level translates into effects at other levels. Relations at animal level were given in Case II of Chapter 5, indicating that higher milk yields can go at the expense of fertility. Relations among zones, for example, refer to issues such as migration of animals, transport of feed across geographical boundaries, animal density (per unit area) and type of animals, i.e., sheep, goat or cattle. Migration of livestock takes place at a large scale, for example, from rainfed areas in Gujarat and Rajasthan to adjoining states like Madhya Pradesh, and Maharashtra in summer and during drought periods (Rangnekar, 1994). Such seasonal (or emergency) migrations are known for systems around the world (Schiere *et al*., 2006) creating feed and livestock markets, and influencing breed composition, animal densities and feed supplies at lower levels of system hierarchy. Consequences are regional pressure on feed resources, which may also lead to social conflicts. In areas of western India, for example, with high buffalo and sheep densities, these species cannot be ignored and strategies for buffalo and small ruminant development have to be incorporated in livestock development plans, as done by BAIF in Zone 6 for buffalo breeding and in Zone 3 for goats (Chapter 2).

Perceived problems versus real problems

Strategies and practices that are successful in one situation (space- and time-specific) are not necessarily successful in other situations, and what appears to be a problem for one may not be a problem for someone else. This is evident in the aftermath of BAIF's initial work on crossbreeding, crop production and horticulture. The first two questions of this thesis about the suitability of technology and methodology should therefore be rephrased, i.e., rather than 'whether there are technologies and methods to be used', 'which methods and technologies should be used in which conditions'. This represents a paradigm shift from objectivist to constructivist approaches (Klir, 1991; Chambers *et al*., 1997; Röling and Pretty, 1997; Ison and Russell, 1999). It also modifies the third question from 'whether there are dynamics' into 'which dynamics should be considered'. The dynamics in approaches and technology focus in agricultural R&D has been discussed extensively in Chapter 7, and they are well illustrated in Table 4 as a reflection on the dynamics in the BAIF programme.

Perceptions of 'real' problems not only differ on scales of time and space, but also depend on who is asking the question. Village communities appear to 'sense' the type of answer most likely to have a chance of success, depending on the question asked and the type of interest expressed by the interviewer. Veterinarians will get different answers to questions than animal nutritionists, administrators or agronomists. In other words, the observer influences the answers and their interpretation (Farrington and Martin, 1988). Also the choice of 'grid' determines the type of problem observed, as discussed under the notion of hierarchy in Chapter 7. A top-down thinking government agent will primarily be concerned about the total milk collected from a village; farmers will look at the price received for the milk, overlooking the problems of milk-collection, or the health of a baby whose share of milk is sold to buy a new radio. In

Table 4. Dynamics in research and extension of BAIF between 1950 and 2000 (adapted from Chambers, 1993).

Period	Explanation of farmers' non-adoption	Solution	Key extension activity	Socio-economic research focus	Predominant research methods
1950s 1960s	Ignorance	Extension	Teaching	Understanding the diffusion and adoption of technology	Questionnaire surveys
1970s 1980s	Farm level constraints	Remove constraints	Supplying inputs	Understanding farming systems	Constraint analysis; farming system research
1990s	Technology does not fit	Change of process	Facilitating farmer participation	Enhancing farmers' competence Understanding and changing professional behaviour	Participatory research by and with farmers

the same line of reasoning, women ask different questions and get different answers than men.

Examples of these differences in perception in the field work are:

- *during group discussions in a village in Gujarat, BAIF found that construction of an approach road was the priority of a group of young men, whereas drinking water was the top priority of the women;*
- *promotion of fodder production in monsoon seasons was an activity of BAIF in Gujarat, where some farmers were reluctant and did not sow the suggested fodder. They cited land shortage and ample availability of greens during the monsoon, desiring to grow fodder in the winter season. Having received this feedback, BAIF switched to providing winter variety seeds for fodder cultivation, which was very well received by farmers;*
- *women in Rajasthan were asked about the problems of dry season feeding of their goats (Rangnekar and Conroy, BAIF, pers. comm., 1998). To the surprise of the questioners the women answered that they experienced no problem with dry season feeding, but had problems acquiring firewood for the kitchen or school uniforms for the children. Further probing revealed that the women had or perceived no problem with dry-season feeding, because they used to sell or butcher their animals before the dry season.*

These examples provide the reasons that forced BAIF to gradually broaden its perspective in such a way that livestock development became a means rather than a goal for overall rural development.

Phases in development

The thesis distinguished three levels of modelling in Chapter 5, three phases of field experimentation in Chapter 6 and three phases of agricultural R&D by BAIF and international agencies. This regularity of three phases was also explicit in a paper on international R&D, which also distinguished three phases (Van Keulen, 2006). In the same manner, there is analogy in Chapter 6 on field experimentation *sensu latu*, in which three phases are recognized, while Simmonds (1986) divides FSR *sensu latu* in three forms of FSR. It is beyond the scope of this thesis to prove the point of numerical logic, but the analogy with Indian mythology which recognizes (four) phases in life is noteworthy: (a) *brahmcharyashram* (learning phase), (b) *gruhasthashram* (entering in family life), (c) *vanprasthashram* (organizing a living for next generations), and (d) *sanyasashram* (living an ascetic selfless life, after which the cycle repeats itself in re-incarnation or to nirvana). The point is not so much to settle on a ‘magical’ number 3, 4, or 7 (Miller, 1956), but to note the *repetition* of phases, inherent in system dynamics (Schiere *et al.*, 2004a). This also came to the fore in Chapter 6 on field experimentation, where the third phase of development at watershed level led to the need for a focused intervention in a 'part', i.e., the improvement of soybean yield and implying that the cycle went back to where it started. Such a shift 'forward to a previous' cycle can also be recognized in the Hindu notion of the repetition of the cycle in the fourth phase of *sanyasashram*. And it is also reflected in the generally four phases of Holling's adaptive cycle (Gunderson and Holling, 2002), as well as being implicit in the notion of creative destruction by Schumpeter (1954).

Ultimately, this might hint at a link between what could be called an 'Eastern' way of *process* thinking and a 'Western' way of *goal* thinking. Of course, this does not imply exclusivity of process thinking by the East' nor of goal thinking by the 'West'. Instead, modern system thinking in the West also tends to re-cognize processes (Prigogine and Stengers, 1985; Klir, 1991; Parker and Stacey, 1994; Hodgson, 1996) and goal thinking seems to invade the East, as suggested in Chapter 7 on dynamics in agricultural R&D, and as obvious in the flood of western business reading on sale in the East. However, the distinction between goal and process thinking provides an option of choice between development paradigms, i.e., equilibrium thinking on the one hand and non-equilibrium thinking on the other. The difference between the concepts of goal and process is also in part linked to differences in degree of control, as dictated by differences in access to resources (Schiere *et al*., 1999a). Where access to resources is high, as in high external input agriculture (HEIA) there is a choice, with associated trade-offs, between feed shortages or reduced health by purchasing them from outside. In the resource-poor conditions of many (Indian) mixed farmers, however 'purchase' from outside is no option, and the only alternative is to adjust to limitations as imposed by the system (see also Chapter 6, Cases II and III). If true, this suggests that process and goal thinking are not necessarily unique to 'East' or 'West', respectively, but more general to 'resource-poor' and 'resource-rich', or, for example, to 'South and North', depending on the grid that is chosen.

Reductionism and holism, a matter of emergence

Throughout this thesis a distinction has been made between reductionist and holistic approaches, a notion strongly related to the distinction between mechanistic and objectivist approaches on the one hand and self-organizing, emergent systems with constructivist notions on the other (Capra, 1996; Ison *et al*., 1997; Ison and Russell, 1999). Also in this respect, the thesis touches upon deeper aspects of system behaviour. The first chapter referred to the notion of '*kamdhenu*', a cow that symbolizes the mother in providing milk and manure and serving many other functions. In that chapter a difference was suggested between multifunctionality (Knickel and Renting, 2000; OECD, 2000) and the holistic concept of '*kamdhenu*'.

The earlier references to objectivist *versus* constructivist and equilibrium *versus* non-equilibrium thinking also refer to the paradigm of mechanistic and emergent system behaviour. It could be suggested, therefore, that a step from one or two functions to multifunctionality eventually leads to emergence of holistic notions. Again, there is no point to suggest a fixed threshold, but there might be a number beyond which there is a 'tipping point', at which the parts of a system aggregate into a whole, leading to a shift from one level in the system hierarchy to another and into a 'holistic' entity (Miller, 1956; Cohen and Stewart, 1994; Hodgson, 1996). The village pond or 'Khet talawadi' for water catchments in that sense also reflects a holistic notion, rather than a collection of individual and unrelated functions.

Concluding comments

BAIF, as a development-oriented NGO, started its development programmes with a focus on crossbreeding of cattle. Subsequently, activities broadened to solving problems associated with livestock development in general. And the informal contacts with the stakeholders evolved into the use of more formal and reductionist monitoring methodologies, including structured questionnaires for baseline surveys, to collect 'objective' information on family structure, assets, livestock, feed resources and awareness about dairy production. This included monitoring of milk production of the crossbreds to support discussions with government officials about the impact of the programme. This focus on livestock systems tended to ignore crop and social aspects (Chapters 3 and 4). This development reflects a remarkable analogy with the dynamics in the work of other research groups such as ICAR in India, and CGIAR at international level (Van den Ban and Hawkins, 1988; Röling 1988; Chambers *et al.*, 1989; Ison and Russell, 1999; Collinson, 2000). Initial successes lead those institutions to copy their work to other regions with different agro-ecological and socio-cultural conditions. Eventually, they were forced to change their methodologies and technologies.

This study describes different approaches that have been used in the rural development work by BAIF, top-down, objectivist and reductionist approaches on the one side, and more participatory, bottom-up, constructivist and holistic ones on the other side (Bawden, 1992; Röling, 1996; Ison and Russel, 1999). Each of the components in the basket of FSR methodologies used by BAIF, both *ex-ante* and *ex-post,* has its own advantages and disadvantages. Based on an informal *ex-ante* analysis of recommended feeding technologies it was decided to address protein and energy deficiencies (Chapter 2). Simulation modelling helped to examine the suitability of specific feeding technologies with a focus on single as well as multiple criteria at animal and farm level (Chapter 5). Upscaling from animal level, implying a reductionist approach, to whole farm level, represents a paradigm shift, with recognition of interconnectedness between crop and livestock components. The *ex-post* analyses illustrated in Chapters 3 and 4 are useful to monitor the performance and to assess the impact of ongoing breeding programmes. Such analyses are useful to re-orient policy makers, development agencies and scientists in discussions on future policies for breeding and support activities, but they are expensive, time-consuming, laborious and inflexible.

Farmers' involvement in testing and modification of technologies is another important tool in technology adoption, but the degree of farmer participation depends on the technologies. Externally controlled technologies such as AI and crossbreeding, require support from outside agencies (Government and/or NGOs), involving structural change in agricultural R&D. For farmer-managed technologies (feeding and animal management), farmer-focused extension methodologies are needed to motivate and adjust the technology to their needs, resources and skills. The role of agencies involved in this type of development activities has to be creative and flexible to match the specific requirements of different technologies with farmers' realities.

Interconnectedness across levels is a reason for system dynamics, as a change in one part of the system results in an effect elsewhere (Klir, 1991). A single-minded focus on the livestock component (sub-system) provides only partial understanding of the farm system, reflecting a reductionist approach, even, where it is illogical to consider livestock in isolation from crops, family labour and other resources, especially in low-input mixed farming systems such as common across India. Hence, livestock development that is closely associated with crop farming has to be studied using an integrated approach. Also holistic approaches are needed to effectively tackle livestock development, including other animals such as buffalo, small ruminants or poultry, as within a farm system such animals compete for (the) limited resources, feed, labour and attention. Strategies for the poorest of the poor, i.e., the most vulnerable and needy group with minimal resources, may need to be developed from a different perspective. BAIF attempts to cope with this diversity by introducing a range of interventions that can match differential resource availabilities, such as improving and/or providing small ruminants, poultry, indigenous milk cow for those who cannot afford high quality feeds.

The issues raised here deal with problems that may imply paradigm shifts for agricultural R&D. An additional difficulty is to establish objective criteria for zoning, considering that different stakeholders have different and changing options about their problems at different levels of hierarchy in time and space. Last but not the least, the open nature of agricultural systems is important, so that they cannot be studied in isolation. Basically, this requires a choice about the objectives for agricultural development, whether aiming at final and objective answers, or accepting that one should go for 'good-enough' and quick and adaptive management.

The BAIF experience is an example in itself. Its history shows how different approaches have been adopted within an organization that changed its development perspective over time and space. This specific history is remarkably well reflected in similar changes at national (ICAR) and international (CGIAR) level. At first, BAIF thought it appropriate to improve the socio-economic situation of farmers through a focus on crossbreeding, as a tool for income generation, in addition to employment and nutrition to improve the quality of life. More than 1.5 million farm families in eight states of the country have benefited, generating additional revenue of an estimated Rs 15,000 million per year through the BAIF programmes (Anonymous, 2005). In the course of time, however, BAIF understood that crossbreeding is not useful at all places, and/or that crossbreeding requires follow-up measures in terms of health care or feed supply. Eventually, it even started to realize, from farmers' perceptions, that in village development, water scarcity can be a more serious problem than low milk yields. Addressing these problems through watershed management and area-based family-focused activities helped not only the livestock owners but also the land owners and the landless with beneficial effects on community and environment, moving its paradigm from reductionist to holistic approaches. Ultimately, and quoting an Indian wisdom, to be successful (in development) one needs commitment and in addition 'tools', 'direction' and among others 'speed' to achieve ones 'goal'. Development can be considered as a continuous process, of which the goals change over time-and-space, shifting from goal to process thinking. Whether the 'goal' is seen as an end point or as a process is a matter of paradigm, but the *Sanskrit* root-word for goal in this case has the meaning of a dynamic 'what one hopes to achieve' rather than a rigid goal. Since development is a dynamic process, the choice of tools (methodology and technology) should be commensurate with the changes that occur in the course of the process of development in the context of time and space. Changes are also inevitable in dynamic organizations involved in rural development such as BAIF.

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Summary

Smallholder crop-livestock mixed farming will continue to be the dominant livestock production system in developing countries. Mixed farming systems produce 92% of the global milk supply, and about 50% of the total milk and meat produced in these systems comes from developing countries. In India, livestock production is predominantly a small-scale rural livelihood activity, and also here forms an integral part of mixed farming systems. Traditionally, livestock served a multitude of functions, i.e., production of milk, meat, manure, for draught, cultural value, and as capital asset for investment and insurance, aggregated in Hindu culture as the cow as 'mother', represented in the holistic concept '*kamdhenu*'. Over the years, dairy farming has become an increasingly important source of family income for resource-poor farmers, and in particular for the landless. As one of the diverse sources of income in mixed farming systems, livestock offers considerable potential for poverty alleviation. At national level, livestock currently contributes 26% to GDP in agriculture, 30–50% to family income and generates substantial employment in rural areas. Even so, per capita milk availability is low (231 g d^{-1}). Low genetic potential, scarce feed resources, poor health management and lack of market opportunities are major constraints for higher production. Increasing human population, declining land availability and dwindling common property resources for grazing lead to increasing dependence on low quality crop residues.

This thesis describes and analyses methodologies and experiences of BAIF (an Indian NGO) in livestock development as a means for rural development. In broad terms, the objectives of this thesis are:

- To identify and assess technologies that under the prevailing farming conditions (agro-ecological and socio-economic) might be suitable for improving production. Technologies in breeding and feeding were selected as having potential for application. Crossbreeding is generally accepted as a means to improve genetic potential for milk production, while various crop residue treatments, as well as supplementation methods can contribute to an improved nutritional status.
- To describe and analyse methodologies for identification and testing of technologies for livestock development in Gujarat (India). This study is based on the use of Farming System Research (FSR) tools, such as *ex-post* and *ex-ante* analysis, on-farm experimentation and other participatory approaches.

The first section (Chapters 1 and 2) of the thesis describes the importance of livestock in rural livelihoods in India. It narrates on livestock population, feed resources and

production and management and looks at development perspectives; BAIF is introduced and its role in rural development. Chapter 2 deals with constraints and options for livestock development in Gujarat. It describes the study area, and the experiences of BAIF with FSR methodology, to identify suitable technologies in breeding and feeding of the animals. Participatory tools such as zoning and mapping supported identification of suitable technologies, such as crossbreeding and supplementation with urea, gotar, and tree leaves.

The second section reports on impact assessment of crossbreeding. Performance data, monitored at fortnightly intervals in different agro-ecological zones, were recorded at farm scale and analysed (Chapters 3 and 4). Crossbreds produced on average 1.8 times higher milk yields than local breeds in all three zones. This resulted in 22% higher household income and 64% higher household gross margin under those market conditions. Crossbreds performed equally well in tribal and non-tribal farming systems. As roughage quality is a major constraint for dairy farming in Gujarat, farmers owning crossbreds adjusted the diet of the animals by feeding extra concentrates (1.4 times more than to local cows). There was no difference in work load and/or labour division in households with and without crossbreds. These results indicate that under the market conditions prevailing in Gujarat, crossbreeding is a technically feasible and economically viable option for mixed farming systems in the State, and therefore an important livelihood option for landless farmers.

The third section describes the use of different methods for '*ex-ante*' analysis, as well as experiences with field experimentation. Chapter 5 explores ('*ex-ante*') the suitability of selected feeding technologies mostly in combination with breeding interventions. Technologies such as urea supplementation, use of concentrate, gotar (pigeon pea leaves), urea-treated straw with concentrates, and leuceana tree leaves were assessed for their suitability in terms of increasing farm income. The first case uses simple partial budgeting to test the feasibility of feeding concentrates. The second case uses a herd dynamics model (PCHerd) to establish the effect of different feeding strategies on various animal production parameters. The third case uses linear programming to study the interactive effects of animal production levels (high-yielding crossbreds *versus* low-yielding local cows), feeding technologies and cropping patterns on farm income in a mixed crop-livestock system. Case I illustrates that concentrate feeding is beneficial to farmers owning crossbred cows, with purchasing power and having access to markets. The multi-criteria simulation with PCHerd in Case II shows that adoption of crossbreeding is more remunerative for landless and tribal farmers than for non-tribal farmers. Feeding interventions were more effective for crossbreds than for local cows. The linear programming exercise of Case III, illustrates, among others, that maximum farm income is achieved at medium milk yields per animal (around 10 kg d^{-1}). Higher milk yields require use of better quality feeds, so that the straws of the grain crops are useless for feeding. In that situation, the farm plan shifts from a grain crop, of which both the grain *and* straw can be used, to cotton only. The three types of modelling illustrate a range in approaches, from a reductionist focus on single criteria to a holistic approach that uses criteria at whole-farm scale. This range in approaches is also reflected in other chapters of this thesis that illustrate studies on and interventions in components (sub-systems) of the farm, as well studies and interventions at whole farm scale.

Four case studies on experiences of BAIF in field experimentation are discussed in Chapter 6. Starting from work on Artificial Insemination as a single activity, BAIF broadened its activities to other components of the farm such as crops, and eventually to the scale of community and even watershed. Moreover, in addition to livestock, to increase family income, it expanded its activities to other issues, such as community health and gender. The case studies deal with selection of methodology and choice of technology for interventions in OFTs ('On-Farm-Trials'), looking at '*with and without*' or '*before and after*'. The 'before and after' approach is more suitable in situations where availability of homogenous groups of farms and animals, logistic support, labour and inputs are constraints. OFTs were also effective in demonstrating to farmers the possibilities for milk yield increases due to supplementation and crop yield increases due to application of micronutrients. In general, OFTs can help in exchanging information between scientists and (resource-poor) farmers, and facilitating acceptance of technologies by farmers.

User-friendliness of the technology, closeness to routine practices and responsiveness to farmers' demands were factors promoting adoption. However, despite initial curiosity and enthusiasm, limited availability of straw in rain-fed conditions and restricted availability of labour appeared major factors adversely affecting adoption of straw feeding methods in those regions, Demand-driven interventions, introduced through participatory approaches stand better chances of adoption at wider scale.

Section four reviews BAIF's experiences in agricultural R&D over the past decades, in the context of similar experiences in other countries and organizations. The swing from attention to parts (the crossbreds) to whole farm systems (and eventually the watershed) can be recognized in all organizations. Also the dynamics from top-down to more participatory bottom-up approaches are not unique for BAIF. This illustrates that R&D in general can be seen as a complex adaptive system, and some factors affecting the selection of R&D approaches and their (lack of) success are reviewed.

The major findings are:

- The criteria for choice of intervention and extension approach may change in time and space, in dependence of stage of development, farmers' (changing) priorities, and target groups. For example, the poorest of the poor, who cannot afford large ruminants, have to be approached with other options, e.g., small ruminants or poultry; concentrate feeding may be useful where market conditions are favourable, but is not an option for owners of local breeds in remote areas.

- Performance monitoring through *ex-post* surveys provides insight in the effects of interventions, such as the performance of crossbreds produced in breeding programmes, but such surveys are time-consuming and labourious, and their results become available relatively late.
- Participatory approaches from the action-oriented FSR&E approach allow more timely assessment of local problems and farmers' priorities. Participatory feedback and construction of an intervention matrix provide the basis for identification of 'recommendation domains', for identification of unexpected issues and for re-orientation of the R&D agenda of (the) development organization(s).
- Participation of the farmers in managing on-farm trials gives them self-confidence, it helps to develop trust between scientists, farmers and extension officers and it provides a platform for interaction and knowledge sharing. It can help in re-orienting the vision on the problem, reconsidering research priorities, and modifying technology, as well as the methodology to be applied.
- Different approaches are needed for different types of interventions (i.e., externally induced and internally self-organized), the one to influence policy makers and the other to motivate farmers. Agencies working in rural development have to acquire the skills to negotiate with and influence these different target groups.
- Initially, though BAIF embraced the FSR approach to build on past experiences in rural development, its efforts were primarily directed towards improving livelihoods through increasing family income using proven technologies. BAIF used different stages of FSR methodologies in different development contexts in time and space, leading to the use of different tools, such as surveys, *ex-ante* analyses and recommendation domains. It also tried to cope with demands generated in the course of the development process, as in breeding (use of indigenous breeds). Whether the methodology is referred to as FSR, participatory approaches or a combination of participatory and demand-led approaches, ultimately it contributes to improved livelihoods of the farm households.
- Crossbreeding can be an important livelihood option in rural development for resource-poor farmers. Especially landless and tribal farmers can benefit, provided they have adequate knowledge and management skills, sufficient feed resources and access to infrastructure such as marketing.
- BAIF's original mindset was on the meaning of the multiple functions of the cow

(‘*kamdhenu*’) for the community. It subsequently shifted to reductionist approaches, focused on parts of the farm (e.g., AI) and then back to the whole farm and even to the watershed scale. The real move ‘away from reductionism’ is, however, not the move from cow to farm scale, but the understanding that the parts should be viewed as components of the total system and have to be mutually adjusted. Essentially, this implies that a change in one place can have unexpected effects somewhere else.
- Each farmer has his own reasons for not adopting a particular technology, for example perceived risks associated with the technology. And resource-poor farmers cannot afford to take too many risks.

The BAIF experience is an example of what can be called a learning system, or alternatively a complex adaptive system. Its history shows how different approaches have been adopted within the organization, as a consequence of changing development perspectives in time and space. Such dynamics are also reflected in similar changes at national (ICAR) and international (CGIAR) level. At first, BAIF thought it appropriate to improve the socio-economic situation of farmers through a focus on crossbreeding, as a tool for income generation, in addition to employment and nutrition to improve the quality of life. More than 1.5 million farm families in eight states of the country have benefited, generating an estimated Rs 15,000 million per year in additional revenue through the BAIF programmes. In the course of time, BAIF found that crossbreeding is not useful in all situations, or that it requires follow-up measures in terms of health care or feed supply. Eventually, BAIF started to realize that in village development, water scarcity can be a more serious problem than low milk yields. Addressing these problems, through watershed development and area-based family-focused activities, helped livestock and land owners, as well as the landless, with beneficial effects on community and environment. In the course of time, BAIF moved from the use of reductionist to holistic paradigms. The changing paradigms in livestock development used over some 30 years of BAIF activities, appear to be shared between ‘West’ and ‘East’. A typical example in this respect refers to the notion of process *versus* goal thinking. As stated in an Indian wisdom for example, to be successful (in development) one needs commitment, and in addition ‘*tools*’, ‘*direction*’ *and among others* ‘*speed*’ *to achieve ones* ‘*goal*’. Development can be considered as a continuous process, of which the goals change over time and space, shifting from goal to process thinking from one phase into another and even ‘going forward’ to earlier approaches. Whether the ‘goal’ is seen as an end point or as a process is indeed a matter of paradigm and it is worth noting that the *Sanskrit* root word for goal has the meaning of a dynamic ‘what one hopes to achieve’ rather than a rigid end point.

Development is a dynamic process and therefore, the choice of tools (methodology and technology) may change in the course of the process of development, in the context of time and space.

Samenvatting

Kleine gemengde bedrijven zullen ook in de (nabije) toekomst belangrijke landbouwproductiesystemen blijven in ontwikkelingslanden. Meer dan 90% van de totale globale melkproductie is afkomstig van gemengde bedrijfssystemen en een belangrijk deel van die melk én het vlees geproduceerd in dergelijke systemen is afkomstig uit ontwikkelingslanden. In India is veehouderij voornamelijk een kleinschalige rurale activiteit, en ook hier vormt die een integraal onderdeel van gemengde bedrijfssystemen. Traditioneel diende vee een veelheid van doeleinden, zoals productie van melk, vlees, mest en trekkracht, culturele waarden en als kapitaal voor investeringen en verzekeringen. Deze meervoudige functies zijn binnen het hindoeïsme geaggregeerd in het begrip koe als ‘moeder’, uitgedrukt in wat in dit proefschrift wordt beschreven met het holistische begrip ‘*kamdhenu*’.

In de loop van de tijd is ook in India de melkveehouderij een steeds belangrijker bron van gezinsinkomen geworden voor kleine boeren met weinig middelen en speciaal voor de landlozen. Als één van de bronnen van inkomen in gemengde bedrijfssystemen, biedt veehouderij een belangrijke mogelijkheid om de armoede op het platteland te verminderen. Op nationaal niveau in India draagt veehouderij op het ogenblik 26% bij aan het Bruto Nationaal Product uit de landbouw en genereert daarbij veel werkgelegenheid. Toch is de melkconsumptie per hoofd van de bevolking laag (230 g d^{-1}). Het beperkte genetische potentieel van de lokale veerassen, (tijdelijk) gebrek aan voldoende goed voer, ondermaatse veterinaire zorg en slechte toegang tot de markt vormen de belangrijkste beperkingen voor verdere ontwikkeling van de veehouderijsector. De groeiende bevolking, afnemende beschikbaarheid van land en inkrimping van de gemeenschappelijke weidegronden hebben geleid tot een steeds sterkere afhankelijkheid van kwalitatief slechte gewasresten als veevoer.

Dit proefschrift beschrijft en analyseert de ervaringen van BAIF, een grote Indiase Niet-Gouvernementele Organisatie (NGO), in veeteeltontwikkelingsprogramma’s als onderdeel van plattelandsontwikkeling in de deelstaat Gujarat in India. In algemene termen beoogt dit proefschrift te komen tot:

- Identificatie en evaluatie van technologieën die onder de heersende omstandigheden (agro-ecologische en sociaal-economische) geschikt zijn voor het verhogen van de productie. Er is een keus gemaakt voor technologieën binnen de veefokkerij en de voedervoorziening. Het kruisen van lokale met exotische rassen is algemeen geaccepteerd als een middel om de melkproductie te verhogen, terwijl verschillende voedersystemen met gewasresten, en het gebruik van krachtvoer mogelijkheden bieden om de voedingssituatie te verbeteren.

- Beschrijving en analyse van methodes voor het identificeren en testen van technologieën die een rol kunnen spelen bij de ontwikkeling van de veehouderij in Gujarat. De studie is gebaseerd op het gebruik van instrumenten uit 'Farming Systems Research (FSR)', zoals *ex-post* en *ex-ante* analyses, testen in praktijksituaties en andere participatieve benaderingen.
- Identificatie van verschillen tussen methodes voor selectie en toepassing van de veehouderijtechnologieën.

In Sectie 1 (Hoofdstuk 1) wordt het belang van veehouderij voor de bestaanszekerheid van huishoudens op het platteland beschreven. Er wordt informatie verstrekt over veebestanden, voederbronnen, productie en management. De rundveepopulatie bestaat, afhankelijk van de agro-ecologische omgeving, uit meer of minder goed gedefinieerde koeien- en buffelrassen. Gedurende de laatste veertig jaar is de totale veepopulatie met ongeveer 1% per jaar toegenomen, met een sterkere groei voor buffels en geiten dan voor koeien. Sectie 1 geeft verder achtergrondinformatie over BAIF als ontwikkelingsorganisatie.

In Sectie 2 (Hoofdstuk 2) wordt meer gedetailleerde informatie gegeven over het onderzoeksgebied Gujarat, gespecificeerd per agro-ecologische zone. De ervaringen van BAIF met FSR-methoden voor het identificeren van geschikte technologieën op het gebied van veefokkerij en -voeding worden geanalyseerd. Participatieve methoden, zoals agro-ecologische en andere zoneringen, transecten, Rapid Rural Appraisals (RRA) en karteringen ondersteunden de keuze van geschikte technologieën, zoals kruisen met exotische rassen en het gebruik van supplementatie met urea, gotar (bladeren van struikerwten) en/of boombladeren.

Sectie 3 evalueert een aantal van BAIF's kruisingsprogramma's *ex-post*, d.i. nadat ze enkele jaren zijn toegepast. Bedrijfsgegevens, verzameld per twee weken in drie agro-ecologische zones zijn geanalyseerd (Hoofdstukken 3 en 4). De kruisingen produceerden, gemiddeld over de drie zones, 1.8 keer zoveel melk dan de lokale rassen, resulterend in een 64% hogere bruto winst uit de melkveehouderij en een 22% hoger gezinsinkomen op bedrijven met kruisingen. De kruisingen presteerden even goed binnen 'tribal' (refererend naar een bepaalde etnische groep binnen India) als 'non-tribal' bedrijfssystemen. De kwaliteit van het beschikbare ruwvoer was een belangrijke beperkende factor voor de melkproductie van de gekruiste dieren, en de boeren probeerden deze beperking op te heffen door bijvoeren van extra krachtvoer (40% meer dan voor de lokale koeien). Totale arbeid en arbeidsverdeling op bedrijven met kruisingen verschilden niet van die op bedrijven met lokale rassen. Het gebruik van kruisingen bleek dus zowel technisch-economisch als sociaal een geschikte technologische verbetering voor gemengde bedrijfssystemen in Gujarat, mits men toegang heeft tot de markt. Speciaal voor landloze boeren bleek het een belangrijke optie voor verbetering van de bestaanszekerheid.

In Sectie 4 worden verschillende methoden beschreven voor *ex-ante* analyses, samen met BAIF's ervaringen met praktijktoetsing van verschillende technologieën op dier-, kudde-, bedrijfs- en stroomgebiedniveau. Hoofdstuk 5 verkent (*ex-ante)* de mogelijkheden van verschillende voederstrategieën, in combinatie met veefokkerij (kruisen), voor gemengde bedrijfssystemen in Gujarat.

Voedersystemen zoals urea-bijvoedering, gebruik van lokaal beschikbaar en commercieel krachtvoer, gebruik van met urea behandeld stro in combinatie met krachtvoer, en gebruik van gotar en leuceanabladeren (een tropische vlinderbloemige boom) werden geëvalueerd.

De eerste case studie gebruikt een eenvoudige partiële budget-analyse om de mogelijkheden van gebruik van krachtvoer te evalueren. In de tweede case studie wordt een dynamisch kuddemodel (PCHerd) gebruikt om de effecten te analyseren van verschillende voeder- en fokkerijstrategieën op een aantal productieparameters. De derde case studie gebruikt lineaire programmering bij het bestuderen van de interacties tussen verschillende productieniveaus van individuele dieren (hoogproductieve kruisingen *versus* laagproductieve lokale rassen), voederstrategieën en gewaspatronen op het bedrijfsinkomen in gemengde bedrijfssystemen. De eerste studie laat zien dat gebruik van krachtvoer voordelig is op bedrijven die kruisingen houden, en die voldoende koopkracht hebben met toegang tot de markt. De multi-criteria simulaties met PCHerd illustreren dat kruisingen winstgevender zijn voor landloze en 'tribal' boeren dan voor 'non-tribal' boeren en dat verbeteringen in voederkwaliteit effectiever zijn voor kruisingen dan voor lokale rassen. De lineaire programmeringstudie laat onder andere zien dat het hoogste bedrijfsinkomen wordt gerealiseerd bij een gemiddelde melkgift per dier (10 kg d^{-1}). Voor hogere melkgiften is voer van betere kwaliteit nodig, zodat het graanstro niet meer gebruikt kan worden. Op bedrijfsniveau leidt dat tot een verschuiving van graanproductie, waarbij zowel de korrel als het stro gebruikt werden, naar verbouw van katoen. De drie typen modelstudies illustreren het beschikbare scala aan benaderingen, van een reductionistische nadruk op enkelvoudige criteria tot een meer holistische benadering waarbij verschillende criteria op bedrijfsschaal worden gebruikt. Dit scala aan benaderingen wordt ook gebruikt in andere hoofdstukken van dit proefschrift waarin studies worden beschreven met betrekking tot, en interventies in, componenten (subsystemen), evenals studies en interventies op bedrijfsschaal.

In Hoofdstuk 6 worden vier case studies beschreven van BAIF's ervaringen met praktijktoetsing van technologieën. Beginnend bij activiteiten rond kunstmatige inseminatie als een op zich staande activiteit, heeft BAIF zijn activiteiten geleidelijk uitgebreid met andere componenten van het boerenbedrijf zoals akkerbouw, en uiteindelijk naar het niveau van de gemeenschap of zelfs het stroomgebied. Daarnaast werden de activiteiten op het gebied van veehouderij aangevuld met andere benaderingen om het gezinsinkomen te verhogen, zoals gezondheidszorg en gender. De case studies hebben betrekking op de keuze van methodologie en technologie voor praktijktoetsing, waarbij vergelijkingen gemaakt werden tussen '*met en zonder*' of '*voor en na*'. De '*voor en na'* benadering is geschikter in situaties waar beschikbaarheid van voldoende homogene groepen van bedrijven en dieren, logistieke ondersteuning, arbeid en inputs beperkende factoren zijn. Testen in de praktijk bleek effectief voor het demonstreren aan boeren van de mogelijkheden om de melkproductie te verhogen via het gebruik van krachtvoer, en gewasopbrengsten via toediening van micronutriënten. In het algemeen kan testen in de praktijk dus helpen bij het uitwisselen van informatie tussen onderzoekers en (armere) boeren.

Adoptie van nieuwe technologieën door boeren maakt een grotere kans wanneer ze voorzien in de behoeften van boeren, wanneer ze gebruik maken van lokale, gemakkelijk te verkrijgen (voeder)bronnen, geen grote veranderingen in de bedrijfsvoering vereisen, en wanneer ze relatief gemakkelijk zijn door te voeren en/of op korte termijn tastbare resultaten opleveren. Ondanks enthousiasme in het begin, bleken bijvoorbeeld de beperkte beschikbaarheid van graanstro onder regenafhankelijke omstandigheden en schaarste aan arbeid belangrijke factoren die de adoptie van de technologie van het gebruik van stro als veevoer negatief beïnvloedden. Technologieën die voortkomen uit vragen van de praktijk en die worden geïntroduceerd via participatieve benaderingen maken een grotere kans op adoptie op grotere schaal.

Sectie 5 analyseert de dynamiek in methoden en benaderingen die door BAIF gebruikt zijn voor landbouwkundig R&D in de loop van de tijd, vanaf haar kleinschalige Ghandi-achtige wortels tot aan het functioneren als een grote ontwikkelingsorganisatie. Deze ervaringen worden besproken tegen de achtergrond van vergelijkbare ontwikkelingen in internationale en nationale (onderzoeks)organisaties in geïndustrialiseerde landen, met aandacht voor de factoren die deze veranderingen beïnvloeden. Het verschuiven van aandacht voor componenten (veeverbetering via kunstmatige inseminatie) naar aandacht voor het bedrijf als geheel (en uiteindelijk het stroomgebied) is in alle organisaties te herkennen. Ook de overgang van een top-down naar een meer participatieve bottom-up benadering is niet uniek voor BAIF. Dit illustreert dat landbouwkundig R&D zich gedraagt als een complex adaptief systeem met zijn eigen dynamiek en de daarmee samenhangende verschuivingen in paradigma's.

Samengevat, zijn enkele van de belangrijkste uitkomsten van dit proefschrift:

- De criteria die gebruikt worden bij de keuze voor de interventie- en voorlichtingsmethoden zijn tijd- en plaatsgebonden. Ze veranderen met de fase van ontwikkeling waarin een systeem verkeert, de (veranderende) prioriteiten van de boeren en de doelgroep. Bijvoorbeeld, de armsten van de armsten, die zich geen grootvee kunnen veroorloven, hebben andere opties nodig (bv. kleinvee of pluimvee) dan rijkere boeren. Gebruik van krachtvoer kan aantrekkelijk zijn wanneer de markt gunstig is, maar het is geen optie voor boeren met lokale rassen in afgelegen gebieden.
- Monitoring achteraf (‘*ex-post*’) via surveys geeft inzicht in de effecten van interventies, zoals de prestaties van gekruiste dieren, maar zulke surveys kosten veel tijd en arbeid, en de resultaten komen laat beschikbaar.
- Participatieve benaderingen uit de actiegerichte FSR&E methodologie maken het mogelijk om de lokale problemen en de prioriteiten van boeren sneller te identificeren. Het gebruik van een interventiematrix maakt het mogelijk om ‘recommendation domains’ te definiëren voor het identificeren van niet-voorziene aandachtspunten en voor het herformuleren van de R&D agenda van ontwikkelingsorganisaties.
- Deelname van boeren aan de uitvoering van testen in de praktijk zorgt ervoor dat ze zelfvertrouwen krijgen, het creëert een vertrouwensband tussen onderzoekers, boeren en voorlichters en het vormt een platform voor interactie en uitwisseling van kennis. Het helpt ook bij heroriëntatie op de problemen, herziening van onderzoeksprioriteiten en aanpassing van technologieën en/of onderzoeksmethodologie.
- Verschillende benaderingen zijn nodig voor verschillende typen interventies (zoals extern-geïnduceerde interventies *versus* intern-geïnduceerde), het ene type om beleidsmakers te beïnvloeden, het andere om boeren te motiveren. Organisaties die actief zijn in plattelandsontwikkeling moeten vaardigheden ontwikkelen met betrekking tot het onderhandelen met verschillende doelgroepen om de verschillende benaderingen te kunnen koppelen.
- In het begin gebruikte BAIF impliciet een FSR benadering om voort te borduren op lokaal gevoelde behoeftes in plattelandsontwikkeling. De nadruk kwam echter spoedig te liggen op eenzijdige verbetering van de levensomstandigheden van de bevolking door het verhogen van het gezinsinkomen via introductie van bewezen technologieën (zoals KI). Later gebruikte BAIF hoe langer hoe meer expliciet verschillende componenten uit de FSR benadering, waarbij op verschillende plaatsen en verschillende momenten verschillende instrumenten werden toegepast, zoals surveys, *ex-ante* analyses en het gebruik van ‘recommendation domains’. Of

deze benadering wordt aangeduid als FSR, participatieve benadering of een combinatie van participatieve en vraaggestuurde benaderingen doet minder ter zake. Het uiteindelijke doel is om een bijdrage te leveren aan het verbeteren van de levensomstandigheden van de huishoudens op het platteland.

- Kruisen met exotische rassen kan een belangrijke optie zijn voor boeren die over beperkte middelen beschikken. Vooral landloze en ‘tribal’ boeren profiteren daarvan, op voorwaarde dat ze beschikken over voldoende kennis en managementcapaciteiten, voldoende voederbronnen en toegang tot de markt.
- De oorspronkelijke ‘mindset’ van BAIF was gericht op de meervoudige functies van de koe voor de gemeenschap (‘*kamdhenu*’). Vervolgens verschoof de aandacht naar meer gefocuste (= reductionistische) benaderingen, met nadruk op specifieke delen van het boerenbedrijf (e.g., veeverbetering), en daarna terug naar het bedrijf als geheel en zelfs naar het niveau van stroomgebied. De essentie van de ‘beweging weg van reductionisme’ is echter niet de verschuiving van aandacht van koe naar bedrijf, maar het begrip dat de onderdelen moeten worden gezien als componenten van het systeem als geheel, en dat ze dus onderling op elkaar moeten worden afgestemd. Wezenlijk betekent dit dat een verandering in één deel van het systeem onverwachte effecten kan hebben op een andere plaats in het systeem.
- Iedere boer heeft specifieke redenen om een bepaalde technologie wel dan niet toe te passen, bijvoorbeeld vanwege de risico’s die aan die technologie zijn verbonden. En boeren die over beperkte middelen beschikken kunnen zich geen risico’s veroorloven.

De BAIF-ervaring is een voorbeeld van wat een ‘lerende organisatie’ kan worden genoemd binnen de landbouwkundige R&D, oftewel een complex adaptief systeem. De ruwweg dertigjarige geschiedenis van BAIF illustreert hoe verschillende benaderingen zijn gebruikt binnen de organisatie als consequentie van veranderingen in ontwikkelingsperspectieven in tijd en ruimte. Een soortgelijke dynamiek blijkt ook te herkennen binnen nationale (ICAR) en internationale (CGIAR) landbouwkundige onderzoeksorganisaties. In het begin vond BAIF het belangrijk om de sociaal-economische omstandigheden van de boerenhuishoudens te verbeteren via een eenzijdige nadruk op kruisingen met exotische rassen. Dat was een middel voor het genereren van inkomen, naast werkgelegenheid en voedselzekerheid, om de kwaliteit van het bestaan te verbeteren. Meer dan 1.5 miljoen huishoudens in acht deelstaten van India hebben geprofiteerd van deze activiteiten, die naar schatting jaarlijks zo’n 15.000 miljoen Rupees (300 M$) aan extra inkomen genereerden. In de loop van de tijd echter ontdekte BAIF dat het kruisen van dieren niet in alle situaties de beste optie is of dat er aanvullende maatregelen nodig zijn, zoals veterinaire zorg en/of het verbeteren van de voedersituatie. Uiteindelijk realiseerde BAIF zich zelfs dat in het kader van dorpsontwikkeling watergebrek een groter probleem kan zijn dan lage melkgiften. Aandacht voor deze problemen via ontwikkeling op stroomgebiedniveau en via op het huishouden gerichte activiteiten ondersteunde zowel veehouders als landeigenaren, met gunstige effecten op het niveau van de gemeenschap en op het milieu. In de loop van de tijd verschoof het ontwikkelingsparadigma van BAIF dus eerst van holistische (‘*kamdhenu*’) naar meer reductionistische benaderingen en later terug van reductionistische naar holistische paradigma’s. Deze verschuivingen in paradigma’s voor veeteeltontwikkeling in de loop van de laatste 30 jaar worden gedeeld door ‘Oost’ en ‘West’. Een ander voorbeeld van verschuivende paradigma’s in dit opzicht is de notie van proces- *versus* doelgericht denken. Een oude Indiase wijsheid zegt bijvoorbeeld: om succes te hebben (in ontwikkeling) is toewijding nodig, en daarnaast *‘instrumenten’, ‘richting’ en onder andere ‘snelheid’ om de ‘doelstelling’ te bereiken.* Ontwikkeling kan hierbij worden beschouwd als een continu dynamisch ‘leer’-proces, waarbij de doelstellingen tijd- en plaatsgebonden zijn. In een dergelijke benadering kan ook het denken veranderen van doel- naar proces-gerichtheid, in een continue ontwikkeling die verschillende fasen doorloopt, en waarbij het zelfs mogelijk wordt om ‘vooruit’ te gaan naar ‘eerdere’ benaderingen. Een voorbeeld hiervan wordt gegeven in Hoofdstuk 6, dat het hele scala aan R&D-benaderingen beschrijft van top-down en door onderzoekers gerunde testen in de praktijk van, bijvoorbeeld, toepassing van KI, via participatieve en holistische benaderingen op de schaal van het stroomgebied, terug (of vooruit) naar meer op reductionistische paradigma’s gebaseerde proeven met sojabonen. Of het ‘doel’ wordt gezien als eindpunt of als proces is inderdaad een kwestie van paradigma en het is in dit verband interessant dat de stam van het Sanskriet-woord voor doel de betekenis heeft van een dynamisch ‘wat men hoopt te bereiken’ eerder dan van een rigide eindpunt.

Concluderend kan worden gezegd dat ontwikkeling een dynamisch proces is. Het ligt daarom voor de hand dat de keuze van instrumenten (methoden en technologieën) in de loop van het proces verandert, zowel in ruimte als in tijd, waarbij voor iedere combinatie van die twee, een meest gewenste combinatie van methodologie en technologie geïdentificeerd dient te worden. Enkele voorbeelden daarvan zijn beschreven in dit proefschrift.

Curriculum vitae

Bhayyasaheb Ramarao Patil graduated from Bombay Veterinary College in 1972 and obtained an MSc in Animal Science from Wageningen Agricultural University in 1995. Since 32 years he has worked as a Senior Executive in the BAIF Development Research Foundation, mainly based at Pune (Maharasthra) and Vadodara (Gujarat), all in India. During his professional career he received training in various aspects of animal production, farm management, extension and Farming System Research at the Institut National de la Recherche Agronomique (INRA, France) and the International Agricultural Centre in Wageningen (IAC, The Netherlands). On behalf of BAIF he has been actively involved in establishing state level farmers organizations and farmer training programmes, planning, implementation and monitoring of multi-disciplinary projects in livestock development, participatory watershed management and applied research in three States of India. He has been associated with collaborative field research of national and international organizations, such as the Indian Council of Agricultural Research (ICAR), various Indian universities, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the International Livestock Research Institute (ILRI) of the Consultative Group on International Agricultural Research (CGIAR), the Natural Resources Institute (NRI) of the UK, the Canadian International Development Research Centre (IDRC) and the Agricultural University of Queensland (Australia). He has been involved in participatory research, development of training modules and extension material at regional and national level, and he served as resource person for various state- and national level committees on watershed programmes, livestock development and poverty alleviation. He has led successful development projects that were recognized by the State and Central Governments, with awards for environment and rural development for the BAIF-GRISERV team in Gujarat. At this moment, he coordinates and develops need-based community development programmes for the rural population in backward areas of Central India.