Ecology and Agricultural Development in Four Villages of Central Karnataka

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In Central Karnataka the farmers have for a long time adjusted their farming methods and strategy to; ecological conditions, seasonal distribution and variability of precipitation and soils. This study concerns four villages. The crop composition around 1970 and the changes are described to show the types of innovation. New fast maturing varieties of food grains have been accepted everywhere, and the use of chemical fertilizers and pesticides has increased dramatically. A shift to cash crop, especially cotton, has occurred in many places. Also described is how the traditional agricultural systems have been adjusted to the innovations. So far they have not prevented the changes, but around 1990 it seems that the development reached a certain limit. If agricultural production has to keep up with the population growth, new practices, strategies and crops have to be identified.

Keywords: *tropical farming systems, agricultural development, Central Karnataka, India.*

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Since independence there has been a fast increase in agricultural production in India thanks to improved practices, new inputs, irrigation etc. The main purpose of the present study is to describe how this kind of development was possible even in a typical dry-land area such as Central Karnataka, and to evaluate whether the kind of development witnessed so far is also likely to continue in the future or not.

The study mainly builds upon findings from four villages in Central Karnataka in South India. The villages were selected in regions with different types of rainfall and soil conditions in order to compare the influence of ecological conditions. The villages are: Thimmapur in Dharwad district (average annual rainfall 800 mm), Thanda in Bellary district (550 mm), Mantraghatta (880 mm), Bassavangangur (1000 mm) both in Shimoga district. Thimmapur and Thanda have been studied in various years from 1975 to 1992, Mantraghatta and Bassavangangur from 1984 to 1992.

The first part of the study deals with the farmers' adjustments to rainfall and other ecological factors, and how these factors restrict the choice of crops and agricultural activities. Afterwards the actual innovations in agriculture are analyzed to find the main driving forces behind the development. Finally the functions of the local agricultural systems are reviewed to see how they reacted to the innovations and whether they have posed restrictions to development or not.

COMMON AGRICULTURAL FEATURES

The four sample villages have several common agricultural traits because they have more or less the same cultural background (a common language), and a similar physical environment.

Many crops are known commonly, and might be cultivated more or less extensively, dependent upon the local conditions, just as well as the design and use of various agricultural implements also have many traits in common.

Sowing is one of the most important agricultural processes, and most of the crops in this study area are usually sown by a three-tined seed drill, the *kurige*, and various accessory implements (seed hoppers etc.). Nearly all crops are sown in rows. By combining the simple implements (seed drill, seed hoppers etc.) in various ways it is possible to produce various cropping patterns e.g. with a certain number of main crop rows alternating with one or two rows of intercrops (locally called *akkadi* crops). The main crop rows might sometimes consist of mixed crops (if the seeds are mixed before sowing). The rows of intercrops (which are sown with the seed hoppers pulled behind the seed drill) might be mixed or pure in the same way, or the various intercrops might alternate with each other in a regular pattern.

The details of these cropping patterns might vary from one place to another, but the sowing methods and the fundamental ideas are very much alike. A particular farmer usually uses the same seed drill for all his crops, with the result that the distance between the rows remains the same; this facilitates interculture later on because the same harrows can be used on all the fields.

All crops are harvested by sickle or simply pulling the plants up. Originally, underground pits *kanneja* were used for grain storage after harvest in most places, and they were very effective in preventing damage by seed pests or rodents.

The cultivated fields are nearly always rectangular as this is the most practical shape for the agricultural operations. The sides of the fields are, as closely as possible, oriented in north-south and east-west directions (probably due to religious beliefs). The orientation of the fields is thus not very dependent upon the slope of the terrain, but as each field is usually more or less levelled out according to requirement, soil erosion is controlled all the same. The fields are thus arranged in more or less prominent terraces according to slope and soil properties. Thanks to this fact

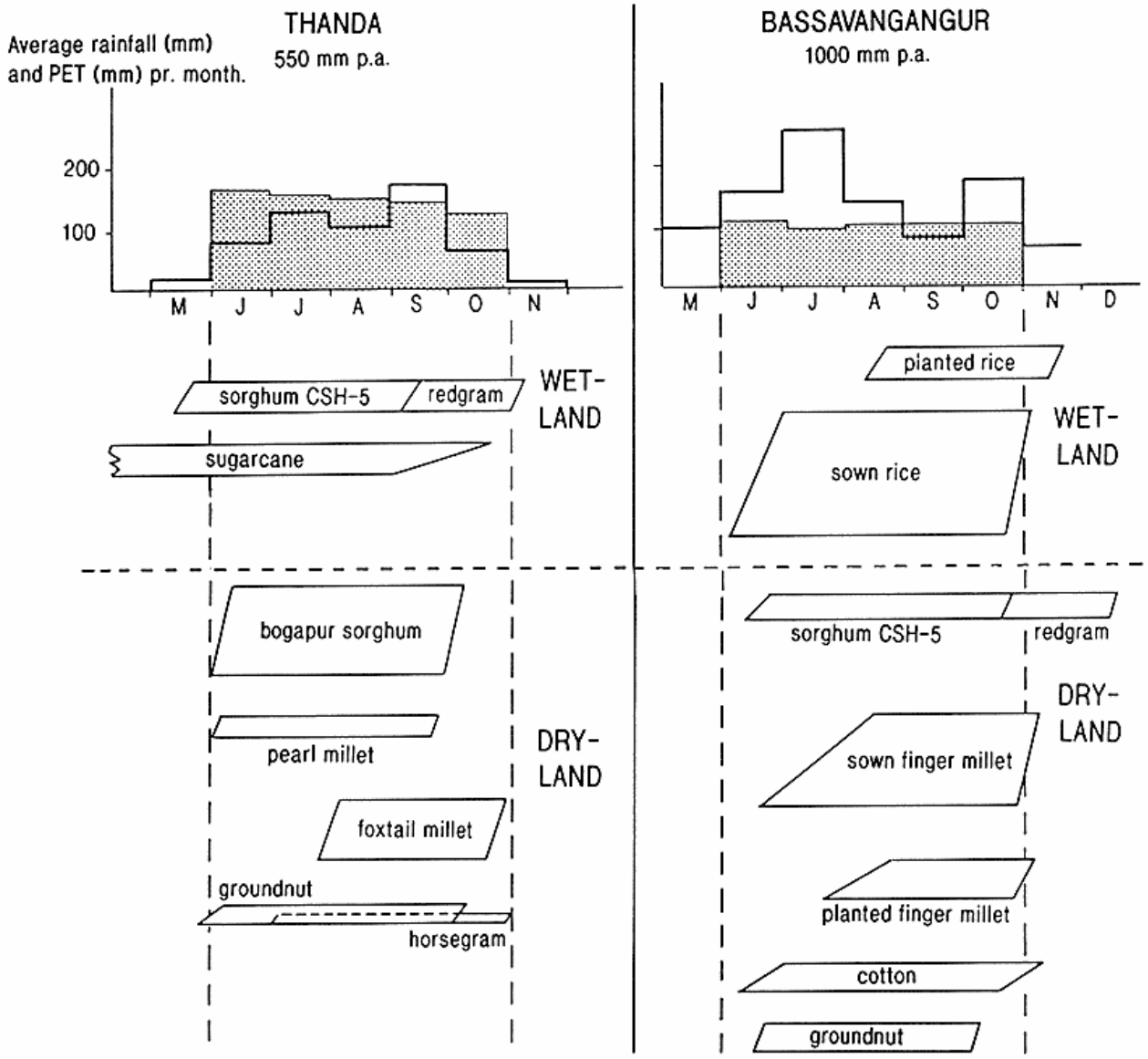

Fig. 1. Pattern of average rainfall and average potential evapotranspiration compared with timing and area of crops in the four sample villages in the year 1989.- Height of boxes is for each village proportional to percentage of total area (c.p. Table 3).

the rainwater infiltrates the soil more easily, and stonefalls or shallow overflow canals are constructed at strategic points to dispose of any surplus runoff in case of heavy rains.

There are many similarities with regard to basic farming strategies. One of the most important in this dry-land farming area, dependent as it is upon an unpredictable and variable rainfall, is to diversify the crop composition as much as possible. By growing several crops with different requirements the risk of complete crop failure in a particular year is reduced, because the timing of various crops and their weak points with regard to environmental stresses are not exactly the same. With regard to crops produced for sale a greater diversity also minimizes the vulnerability to price fluctuations, as these do not usually covariate for various crops. Finally the peak loads in agricultural work also tend to be levelled out by a greater diversity, as the timing of various operations is usually slightly different for the various crops.

Diversification also facilitates crop rotation, which the

farmers are actually very conscious about in order to prevent plant diseases. Often some crops are better adapted to some soils than others, and in some places, due to variation in soil properties, this itself increases the diversification.

Intercropping is another way to insure against deviations in rainfall, because the intercrops (mostly pulses) often have a longer duration of growth as well as other types of root systems than the main crop. In addition to that, intercropping has many other beneficial effects such as; a better use of the surface area throughout the whole season (intercrops often spread out and continue to grow after the harvest of the main crop), fixation of atmospheric nitrogen, and contribution to a more varied and protein rich diet.

The principle of crop diversification is countervailed by the principle of profit maximization, according to which only crops with high output should be grown. The principle of crop diversity might help the initial introduction of a new crop (or variety) and secure its continued use.

The crop composition of a particular dry-land locality is thus likely to change whenever there are fluctuations in prices, but it will on the other hand hardly ever change completely in favour of only one or two profitable crops. (In wet-land areas with assured irrigation, the risk of crop failure is less, so in these areas it is common to have just one, or preferably two of the most profitable crops for rotation.) Due to the general population increase in rural areas, all four sample villages have now reached the stage where nearly all the cultivable land is required for cultivation every year. The cropping index has increased to a maximum, with cultivation of *hingari* (second) crops wherever possible. The number of livestock is usually also at a maximum level, so that all available fodder resources are used. Even minor irrigation has often been extended as much as possible.

All this implies that the change of one element in the agricultural system is very likely to influence one or more of the other elements too.

ECOLOGY AND AGRICULTURE

This section deals with the various types of agricultural adjustments to climate and other ecological factors. The purpose here is to determine which are the most severe ecological constraints to e.g. crop composition and agricultural development.

The amount and timing of rainfall is one of the most important ecological factors in dry-land agriculture. The monsoon climate has two maxima; the first in July and the second in October (or September in Thanda village (c.p. Fig. 1). The SW-monsoon lasts from May to September, and is followed by the SE-monsoon from October to December. The crops which are sown during the early rains (June, July) are locally called *mungari* crops (*kharif*), and the crops sown during September or October are called *hingari* crops (*rabi*).

The soils of this area are mostly vertisols (black soils) or alfisols (red soils) according to the seventh approximation, U.S. Department of Agriculture. Among the four sample villages, most of Thimmapur and a minor part of Mantraghatta have black soils, the rest of the total area is covered by red soils.

The various agricultural adjustments to rainfall might be divided into 1) the more permanent adjustments in strategies and practices which relate to the average yearly amount and timing of the rains, and 2) the more variable (ad hoc) adjustments made in a particular year according to the actual variations.

Primarily the farmers adjust to the average rainfall pattern by selecting crop varieties of a suitable duration combined with a proper choice of sowing time. The selected cultivars should be able to withstand those ecological stresses which are most likely to occur in the growing season.

With regard to adjustment in farming practices, it is for example more common to transplant paddy in areas with very high rainfall (e.g. Central Malnad) and to sow directly in areas with comparatively less rainfall (e.g. Bassavangangur village). Within its range of adaptation the same principle is valid for finger millet whose yield also becomes better if it can be transplanted.

Harvest methods might also be adjusted to climate. The heads of sorghum are thus harvested separately and brought for drying at a protected place in those areas where the harvest season is generally rainy (e.g. Mantraghatta), whereas the whole plant is harvested at once and even stored in stacks in the fields where the harvest season tends to be dry (e.g. Thanda).

Row distance may sometimes be adjusted to average rainfall (narrow distance in wet areas, and broader gap in dry areas), but the farmers are not conscious of this adjustment which probably came gradually as it was slowly realized which distance gave the highest yield. Another type of adjustment, which is nearly irreversible, is seen in the village of Bassavangangur, where extensive areas have been terraced very carefully (around 1950) in order to increase the paddy area.

Short term adjustments are always made for processes such as; tilling, interculture, spraying and harvesting which all depend upon the moisture of the soil or plants. The time of sowing can also be changed, but preferably not so much that it causes either overlapping between other agricultural activities later or the harvest to fall in a rainier period.

The entire farming strategy is sometimes adjusted to the actual rainfall. One good example of this is paddy cultivation in Bassavangangur, where as much of the paddy as possible is sown early if the early rains are moderately good. In this way, at least some output is assured. If the early rains are scanty, then the farmers prefer to wait, hoping that it might be possible to transplant paddy about two months later, by which time some water has collected in the tanks. They will also wait and plant later if the early rains are extremely strong and the tanks fill up at once. The farmers actually prefer transplanted paddy (which usually consists of modern high yielding varieties) to drill sown (usually local, more drought resistant varieties) due to the higher yield of the transplanted varieties.

In Bassavangangur, the farmers said that, with regard to finger millet on dry-land, they would transplant if the soil moisture level was high, but sow if the soil was drier, given normal conditions. In Mantraghatta, the farmers said that they would sometimes sow sorghum immediately if the early rains were heavy but would rather wait for some time and transplant finger millet later if the early rains were light.

More profound ad hoc adjustments are especially common in connection with the *hingari* period because the late rains vary greatly from one year to another. The farmers in Thimmapur can to some extent estimate how the late monsoon rains are going to be from a few simple signs in the clouds, showers and wind direction. If the signs are good, then the preparatory tilling is done slowly and carefully, and the crops are selected according to the farmers' needs. If the signs are bad, then the *hingari* crops are usually grown along with the remaining soil moisture only, and the preparatory tilling is fast and the seeds sown as soon as possible. In this case crop selection depends upon how much water is stored in the soil.

Sometimes the crop composition is adjusted to the soil conditions. In Thimmapur, it has now (1989) become more common to grow one slow-maturing crop (either sorghum cum redgram or cotton) on the red soils, where the water retention capacity is low, whereas it is more common to grow two crops (*mungari* + *hingari*) per year on black soils, where the water retention capacity is high. In Mantraghatta, mainly sorghum (or groundnuts) are grown on the black soils, whereas all crops can be grown on the red soils.

Tilling and the choice of implement are highly dependent upon soil type and moisture content. Soils with less resistance such as sandy soils or black soils are thus mostly tilled with a blade harrow, whereas more clayey soils with high resistance are mostly tilled with pointed wooden or iron ploughs.

In spite of the various adjustments mentioned in the passage above, crop failures are still quite common in dry-land agriculture, even in places with reasonable good rainfall on average and good soil conditions. In Thimmapur, which has the best plant growth conditions among the four sample villages, all the crop harvests were fine in 1975, but in 1976 part of the sorghum failed due to a shortage of rain. The following years' harvests are not known, but from 1985 to the *mungari* season of 1987 all crops failed due to severe drought. In the *hingari* season 1987 the chickpea failed due to excess of rain, but the other crops, wheat and white sorghum, were fine. The strong *mungari* rains in 1988 caused heavy losses to groundnuts (because the pods rotted and the weeds could not be removed in the wet fields). In *mungari* 1989 most of the crops except sorghum had a reduced yield due to dryness, and the chillies failed completely. Also in *mungari* 1991 groundnuts yielded less due to an excess of rain, but in *hingari* many crops failed due to a shortage of rain. In *mungari* 1992 many potato seeds were spoiled due to excess rain, while *hingari* is not known for that year.

Thus, due to the risk of crop failure, the principle of crop diversity has to be observed even in the most favourable areas, such as in Thimmapur, but this practice limits the expansion of such profitable crops as cotton and potatoes due to the high cash input involved. It might be possible to grow most of the known tropical crops in places with favourable ecological conditions, but many crops are excluded here due to their low yield potential.

In areas with more adverse ecological conditions some crops would have to be entirely excluded from cultivation if they failed too often, and that might give a chance to some of the low yielders, as long as they were more tolerant to climatic stresses or their duration was so short that they could be grown at a time of year when extreme conditions (e.g. dry spells) are less frequent.

Actually the geographical distribution of the traditional crops can be explained by a few parametres such as ecological tolerance and yield potential. The crops might be ranked on a simple scale according to tolerance of humidity or dryness respectively. At the top of the scale is rice, which tolerates extreme moisture, but not much dryness, then follows finger millet, which tolerates humidity (but not stagnant water as rice) and also dryness to some degree. Sorghum tolerates less humidity than the previous grain, but more dryness. Some sorghum varieties e.g. bogapur sorghum or white sorghum tolerate extreme dryness. Pearl millet is the main crop in the driest parts of India; actually it is not much more drought resistant than sorghum, but it is much faster maturing (3½ - 4 months compared to 4 months of sorghum).

Groundnuts have a broad range of tolerance, nearly like finger millet and sorghum. Foxtail millet is not drought

resistant, but has a very short period of growth (2½ - 3 months), and might therefore be fitted into the crop calendar of e.g. dry places like Thanda. The yield potential of pearl millet, groundnuts and foxtail millet is low compared to other grains. Among the *hingari* crops, wheat and white sorghum are used thanks to drought resistance, the chickpea and horsegram thanks to short duration of growth.

The main ecological features and geographical distribution of crops among the four sample villages are as follows:

Thimmapur has a precipitation (800 mm p.a.) suitable for most crops. The moisture retention capacity of the soil (black soil) is also high and protects the crops against intermittent drought just as well as it prolongs the growing season after the rains have finished. The plant growth conditions are thus good even in the *hingari* season. Sorghum and groundnuts were the main *mungari* crops around 1975, and wheat, white sorghum and the chickpea the main *hingari* crops. Finger millet is not suitable here because it grows rank on black soil. Foxtail millet might be mixed with groundnuts, because it can be harvested simultaneously (short duration) and does not there fore obstruct the following *hingari* crop.

Thanda is very dry (550 mm p.a.) and the soils are also very poor and sandy. There are nearly no *hingari* crops (only a relay crop of horsegram in groundnuts). Here finger millet, for example, is generally excluded due to the dryness, whereas more droughtresistant crops such as bogapur sorghum, pearl millet etc. are more suitable. There are also several other adjustments to the dry climate in this village. The intercrops (redgram or horsegram) are thus sown pure in their own rows (with no admixture of the main crop). The most sandy soils are characterized by having even two rows (not one as usual) of intercrop (horsegram) alternating with four rows of main crop. By this arrangement the number of plants per unit of area is reduced. The main crop, bogapur sorghum, is usually mixed with pearl millet (in order to reduce the risk of complete failure), and now (1992) it has also become more common to mix it with hybrid sorghum because this variety is appreciated for its grain, whereas bogapur sorghum has good qualities as a fodder crop. Actually, hybrid sorghum is not resistant to striga infection like bogapur sorghum, so this practice is somehow dangerous. With regard to groundnuts, both bunching and creeping varieties are grown, along with foxtail millet varieties either with bigger or smaller spikes. This variability is probably another adjustment to drought as the common stand-by system if the first sowing fails; failed sorghum might thus be replaced by pearl millet, failed foxtail millet by the sunflower.

Mantraghatta has an almost ideal precipitation for most crops (880 mm p.a.). Furthermore, the soils (mostly clayey redsoils) are quite good. It is possible to grow several *hingari* crops if the late rains are good. Sorghum and finger millet supplement each other well in various aspects (timing, soil preference and cooking qualities), and were originally the most common crops. Groundnuts are often difficult to harvest on clayey soils, as are found here, due to hardness, and are therefore rarer.

Bassavangangur has a relatively high precipitation (1000 mm p.a.) which excludes some crops (e.g. sorghum) but favours others (rice). The soil is a rather poor sandy redsoil (leached) with a low moisture retention capacity. Due to this, and because sowing is delayed due to the heavy rains in June, there are no *hingari* crops except e.g. horsegram after groundnuts. The most common crops are finger millet and groundnuts (and after 1970 tobacco) on dry-land, and rice on wet-land.

That it really is the average climatic conditions which sometimes exclude some crops is seen from the fact that farmers often change the crop composition if there is a more permanent change in the climate (over 2 years or more). This was seen for example in connection with the drought of 1984 - 1987 when sorghum and cotton became more common in Bassavangangur, groundnuts and sesamum more common in Mantraghatta and the sunflower more common in Thanda.

For this section it can be concluded that milder ecological constraints (e.g. variability in precipitation), which enforce some diversification of crop composition, are found everywhere. In addition to these, even more severe constraints (e.g. a too small or too large average precipitation), which exclude a smaller or larger number of crops from cultivation, are found in some places.

AGRICULTURAL INNOVATIONS

The previous sections described some of the more common features of traditional agriculture without taking more recent developments into account. This section describes which innovations have been more common during recent years. Those changes which have occurred in the four sample villages during the directly observed periods are described in most detail. The main purpose of this section is to find out which changes and innovations were most readily accepted by the farmers and why.

Originally the farmers mainly cultivated crops such as; foodgrains, pulses, oilseeds and minor fibre crops for their own consumption and use, but gradually they began to turn to cash crops, if not for any other purpose, then to pay taxes. The technology also evolved gradually. Stonerollers for threshing were introduced around 1920, and the simple wooden ploughs (*desi* or country plough) were gradu-

ally improved by inserting iron points etc. Later on, various blade harrows and iron ploughs of western type were introduced.

The use of chemical fertilizer increased dramatically after 1970, and agriculture has now become very dependent upon this input. It was readily accepted due to the spectacular effect upon crop yield. Actually most soils had been exhausted due to inefficient recycling of plant nutrients; some of the manure was thus used as fuel and many plant products (grains, oilseeds, cotton etc.) sold out from the farm. The farmers quickly learned how and when to apply the fertilizers, and also invented several implements (resembling seed hoppers) for the correct placement of it. They have also, to some extent, learned to apply a reasonable dosage and to give all the phosphate and some nitrogen in the first application, then mainly nitrogen in the second application. But even so the farmers do not fully understand some of the more theoretical problems, for example as to why the correct combination of N, P and K is so important and how to adjust to the climate and soil conditions.

The use of pesticides has also gradually become important for such crops as; rice, cotton, potatoes, some pulses, and in some places groundnuts or sorghum (e.g. in Thanda). The farmers are much more confused with regard to this input than with regard to chemical fertilizers; they have possibly been directly misinformed by agents who only wanted to increase the sale. The farmers are not often able to identify plant diseases and insect pests correctly, nor do they know which pesticide to use for which ailment; they are also not fully aware of the health and environmental hazards involved.

The new hybrid or high-yielding varieties of food grains (sorghum, finger millet, rice etc.) were very soon accepted by the farmers, mainly because the shorter duration of growth made it easier to avoid the effect of dry spells at the end of the season, and also due to reduced exposure to various pests (the crops were harvested before the pests could multiply too rapidly). In addition the new varieties also responded better to chemical fertilizers. The farmers had a good ability to select the locally most suitable varieties (with regard to duration, grain quality, resistance etc.), thus around 1984 CSH-5 sorghum was common, while, later, this variety was replaced in some areas by CSH-9 (which had a better fodder quality), and in 1992 many new varieties were available which were produced and marketed by various private companies.

Groundnuts were introduced to Karnataka as a cash crop around 1930, and soon became very important in several places. This crop is often preferred by the poorer farmers because its need of chemical fertilizer is relatively small. It is also well-suited to rotation with various other crops. The farmers are not particularly concerned about varieties, even if some hybrids are available, and they usually only distinguish between bunching and creeping varieties.

There are several minor cash crops in the area which now and then, in special situations, might become of importance. For instance, maize was cultivated extensively as a cash crop in Mantraghatta in 1991 and 1992, probably because it did not need such heavy cash inputs as cotton. In the same village it had been cultivated in 1983 in a place which had remained too wet to sow sorghum due to flooding. In 1984 - 1987 the sunflower was cultivated very extensively in Thanda, partly on dry-land, partly as a second crop on wet-land. It probably became more popular during the drought thanks to its short duration of growth, but after a severe pest attack in 1987 it lost most of its popularity again. The pulses greengram and the cowpea gained some importance in Thimmapur because they were grown as early intercrops in the cotton fields.

In the sample villages, cotton has now become the most important cash crop. For a long time there has been a steady renewal of varieties as the old varieties have become susceptible to various pests and diseases. The fact that they need very intensive spraying is still a problem. In Mantraghatta, the cotton area increased dramatically in 1984 when the new hybrid variety DCH-32 was introduced, probably because the farmers had high hopes about its yield capacity and drought resistance. Later on, the area under cultivation declined during the drought (1985-1987), but when prices began to rise after 1987, the area was again expanded (c.p. Table 2). The development was probably similar in Thimmapur, where other varieties of minor importance have been cultivated for a long time (c.p. Table 1). In Bassavangangur, the cotton area expanded during the drought (1984-1987); previously the preci pitation had been a little too high for this crop, but even during the following years and also in 1992 some cotton was still grown in spite of the fact that the precipitation had increased again. In Thanda, cotton is only grown with minor irrigation as it is otherwise not profitable here.

With regard to ecological constraints then, cotton does not tolerate too much humidity, and in areas with less assured rainfall it is too risky a crop because the cash input required (chemical fertilizer and pesticide) is very high. In addition to that, its duration of growth is also relatively long (5 months).

The increase in prices after 1987 was due to a general expansion in the textile industry, and a special high demand for the long fibres of the DCH-32 variety. Due to its rising popularity, the demand for its seeds increased, and

Year:	1975	1976	1987	1988	1989	(Marginal farmers 1989)
Long-term crops:						
Cotton			16.8	15.6	28.2	25.4
Hybrid sorghum	47	44	14.4	21.9	14.9	4.1
Chillies	6	12	NA	10.1	9.0	23.2
Mungari crops:						
Potato			18	7.2	17.7	10.1
Groundnuts	47	44	45	40.5	20.8	22.9
Pea				0.8	4.6	4.6
Green gram			5	1.6	4.0	8.5
Tomato				2.3		
Others					0.8	1.3
Hingari crops:						
Wheat	-	42	31.0	-	20.9	
Chick-pea	-	5	4.5	-	12.0	
White sorghum	-	0	32.0	-	13.0	
Safflower	-	0	NA	-	1.8	
Others		2			0.2	
All long-term crops:	53	56	32	47.6	52.1	
All short-term crops:	47	47	68	52.4	47.9	

Table 1. Crop composition in Thimmapur village in various years.

Year:	1984	1986	1987	1988	1989
Bigger holdings (above 6 acres):					
Hybrid sorghum	26.7	20.5	32.6	22.7	28.9
Finger millet	35.6	39.9	30.1	38.4	38.1
Groundnuts	7.8	17.8	14.3	10.5	1.9
Cotton	29.9	21.8	23.1	28.4	31.1
Sorghum percentage of sorghum plus finger millet	42.9	33.9	52.0	37.1	43.2
Smaller holdings (1-4 acres):					
Hybrid sorghum	29.0	25.4	21.4	27.0	26.0
Finger millet	34.6	46.3	44.9	39.8	40.9
Groundnuts	5.1	7.9	16.5	14.3	2.0
Cotton	31.3	20.5	17.2	18.9	31.2
Sorghum percentage of sorghum plus finger millet	45.6	35.4	32.3	40.4	38.9

Table 2. Crop composition in Mantraghatta village in various years on smaller and bigger holdings.

sometimes fake seeds were sold. In 1988 many farmers in Thimmapur and Mantraghatta suffered heavy losses due to this.

The potato has only been successfully introduced in one of the four sample villages, viz. Thimmapur, and that too probably only thanks to a special extension effort from the training and visit project (T&V) in 1985 and 1986. Actually, the crop failed in both those years due to drought, but the farmers were convinced about its future use even then. The necessary cash input for this crop is even higher than for cotton. Moreover, seeds are costly, and that might be the reason why it is only grown under optimal ecological conditions.

With the introduction of the potato, farmers have had to learn many new technologies (preparation and protection of seeds, placement and timing, correct spraying and post-harvest storage). Furthermore, they have had to learn about the market (even new seeds from North India have to be purchased every year).

1989	Thimmapur		Thanda		Mantraghatta	Bassavangur	
Crop:	Mungari	Hingari	Dry-land (75%)	Wet-land (25%)	Dry-land	Dry-land (50%)	Wet-land (50%)
Sorghum CSH-9	14.9				27		
Sorghum CSH-5				47		6	4
Bogapur sorghum			45				
Hvid sorghum		13.0					
Foxtail millet			30				
Pearl millet			13				
Wheat		20.9					
Finger millet			0.5		37	55	4
Rice			0.5	6	1		88
Cotton		28.2			30	12	4
Groundnuts	20.8		10		2	16	
Potato	17.7						
Chillies		9.0	0.5		1	1	
Pea	4.6						
Vegetables					1		
Green gram	4.0						
Cow-pea					0.5	0.5	
Chick-pea		12.0					
Safflower		1.8					
Sunflower			0.5		0.5		
Tobacco						10	
Sugar cane				47			

Table 3. Crop composition in all four sample villages in the year 1989.

1989	Thimmapur		Thanda	Mantraghatta	Bassavangur
Crop:		Hingari			
Red gram	1.49		7.54	4.44	0.94
Green gram	8.45		-		0.48
Cow-pea	2.30		-	0.04	0.96
Horsegramum	-		6.9	0.19	-
Field bean	-		-	1.54	0.76
Groundnuts	0.40		-	-	-
Pea	1.00		-	-	-
Tomato	-		-	1.50	-
Niger	-		2.1	0.37	0.17
Sunflower	-		1.5	0.04	-
Sesamum	-		0.9	-	-
Foxtail millet	1.04		-	-	-
Pearl millet	-		9.0	-	-
Safflower		1.67			
White sorghum		2.87			

Table 4. Area of various intercrops and mixcrops on dry-land in the four sample villages in 1989.

Tobacco cultivation was introduced to the Bassavangangur area around 1970 because a tobacco company (ITC) had found this area suitable, as firewood from a forest area nearby could be used for drying the tobacco leaves. Indeed, this crop might be cultivated almost everywhere because its leaves grow continuously and thus will be of good quality, at least during moist periods. Only the wealthiest farmers in Bassavangangur could afford to start tobacco cultivation due to the heavy initial costs involved in the construction of a drying plant (tobacco barn) and the heavy costs of fertilizer and labour afterwards. The farmers are entirely dependent upon the company for the sale of the dried leaves. Even concerning the drying process itself, they are dependent upon migratory skilled labourers from Andra Pradesh.

In Thimmapur, a few farmers were convinced by some agents to start the cultivation of tobacco in 1992. The agents gave all the necessary information about cultivation methods and also supplied all the necessary inputs, even materials for a drying shed (in this case the leaves just had to be dried in the shade, without the use of any fuels).

With regard to the various cash crops, the development in the four sample villages might be summarized as follows:

Thimmapur *mungari* season. The area of cotton (DCH-32) increased from around 1984 along with the intercrop pulses greengram and the cowpea. The potato was introduced in 1985, tobacco in 1992.

Thimmapur *hingari* season. Due to uncertainty about the rains, the farmers did not like to use chemical fertilizers in the *hingari* season, and there was thus not much scope for new introductions, only the "kiran" variety of wheat was tried one year although without success.

Thanda dry-land experienced no real changes, except for some minor irrigation established from 1970 to 1989.

Thanda wet-land has long been cultivated with sugarcane and rice in years when water has been available in a storage tank.

In Mantraghatta, the cotton area increased from 1984 thanks to the new variety DCH-32. Many new plots acquired minor irrigation in the period from 1987 to 1989. There was an increase in the area under maize 1991 and 1992.

In Bassavangangur, tobacco was introduced in the area around 1970. An increase in the cotton area occurred in 1984 (DCH-32). The area under groundnuts was very big in some years e.g. 1991 and 1992. A steady increase in dairying has been possible thanks to available grazing areas and a ready market.

It is thus seen that most introductions of new crops (especially if they need heavy inputs) occur in ecologically favoured areas and seasons.

With regard to the various types of innovations, those which had obvious practical advantages were readily accepted. This was the case with several new implements, the use of chemical fertilizers and the high-yielding or hybrid varieties of food grains. Moreover, these innovations were not usually costly or else the output/input ratio was high. They were accepted in all areas, even those with the most adverse ecological conditions. Minor irrigation was also introduced in all areas with suitable groundwater resources (e.g. Thanda and Mantraghatta), but only by the wealthier farmers who had enough land as security for loans.

Some minor cash crops are generally known in the area, and their cultivation might increase as soon as there is proper price incitement or some other suitable conditions in a particular area (e.g. groundnuts, hybrid maize, the sunflower, pulses and chillies). Neither do these minor cash crops need much cash investment. With regard to the boom in the cotton area, this was partly due to the introduction of the new hybrid variety DCH-32 and the increasing demand and higher prices afterwards. Pesticides were usually only introduced if they were necessary for spraying cotton or other cash crops. With regard to the still more complex and capital intensive crops such as the potato, then it appears that a combination of price incentive, proper extension effort and safety were of importance. The same has been the case with tobacco, where the farmers are extremely dependent upon outside persons with regard to marketing and, sometimes, production.

In many cases, innovation was dependent upon an offer or new invention from outside such as chemical fertilizers or new varieties. It would therefore be a serious constraint to development if the public (ultimately science) did not come foreward with any new ideas or refrained from educating the farmers properly in their use. The innovation process is thus mainly driven by new scientific inventions or by new price incentives, and conversely it might be restricted by various ecological constraints as described.

The farmers have often been very fast and flexible in adopting various innovations, where ecological constraints have not prevented it. The farmers were especially receptive with regard to practical methods which they could observe and understand directly, but they had more difficulty with solving more abstract problems. They were thus successful in selecting the most suitable new crop varieties and in understanding practical aspects of fetilizer use, but not however with mixing various types of fertilizers in the right proportions and the like. When using pesticides, the farmers make many mistakes. It is likely that they will need intensive training and institutional backing before being capable of handling still more complicated inputs (e.g. biofertilizers) effectively.

Most of the agricultural changes occurred one step at a time. There were thus no examples observed of more integrated solutions with several innovations introduced at a time as e.g. mechanization combined with a simultaneous change in livestock composition or the like.

CHANGES IN THE AGRICULTURAL SYSTEMS

This section discusses whether any constraints are created by the agricultural systems themselves. These constraints might be practical, economic, social or cultural.

Among the four sample villages, Thimmapur has been observed during a comparatively long period, and this village is also relatively free of ecological constraints, so

this is an ideal place to study how primary changes in agriculture (in this case the increase in area of various cash crops) have influenced the rest of the agricultural system, and how far the system might have resisted change. Table 1 shows the overall change in crop composition in Thimmapur, and it is seen that the diversity of crops has increased during the period 1975 to 1989, which was actually an advantage for the system (increased safety) in addition to the other gains (increased income).

The original strict rotation, based on the two *mungari* crops groundnuts and sorghum, was relaxed as other crops were introduced. This did not have any bad effects and there were no restrictions to the new crops on this account. The total production of sorghum (the main food grain) has probably remained unchanged because the decrease in area of hybrid sorghum was compensated for by an increase in the area of white sorghum in the *hingari* season. The intercrop redgram can only be grown along with hybrid sorghum (as the *hingari* season is too dry for it), but it was gradually sown more densely as the area of hybrid sorghum decreased. The production of two other intercrops, viz. greengram and the cowpea in cotton fields also increased as the area of cotton increased. There has thus probably not been any resistance to change due to food grain considerations. One of the most important changes was that the number of livestock had to be reduced, because many of the new crops (e.g. cotton and the potato) did not have any suitable fodder component. This loss was, however, tolerated by the farmers because they benefited from an increased production of cash crops and thereby increased their general income.

Table 2 shows the crop composition (for the four main crops only) in Mantraghatta village during the years 1984 to 1989. There might have been some changes similar to those in Thimmapur when the area of cotton increased between 1983 and 1984, but unfortunately the situation before 1984 is not known. The only observation was that the fieldbean was gradually given up as an intercrop with finger millet and instead cultivated as a mixcrop with cotton. The change occurred because it was discovered that fieldbean was eaten by stray cattle after harvest when grown with the new short duration finger millet varieties.

Thus it does not seem as if the agricultural systems in these two villages so far have been a hindrance for changes to any major degree. But it should be considered whether the situation as it was in e.g. 1989 might represent a kind of climax in development, and whether further expansion of e.g. cash crops might not be resisted for various reasons (e.g. violation of the principle of crop diversity).

Table 3 indicates the areal percentage of various main crops as it was in 1989 in the four villages. In Thimmapur, the balance between long-term crops (streaching over both *mungari* and *hingari* seasons) and short-term crops remained nearly constant with around 50% of the area devoted to each. Thus, this balance certainly seems to be important, possibly because it ensures a more equal distribution of the workload between the *mungari* and *hingari* seasons. If the area of long-term crops (sorghum, cotton and chillies) has to remain constant, then the area of cotton cannot increase much above the present 30%, because the farmers would probably also like to grow some chillies (a low input cash crop) and hybrid sorghum (the most stable food grain). Concerning the *mungari* crops, it is not likely that the cultivation of the potato will expand much more because that would be too risky due to the heavy cash input. It seems that the crop composition really has reached a constant level. This was confirmed by a short survey in 1992, according to which the areal percentages were nearly the same as in 1989.

With regard to the dry-land in Thanda, the ecological conditions prevent the introduction of new cash crops (except for some short duration crops e.g. the sunflower). The balance between the three food grains (bogapur sorghum, pearl millet and foxtail millet) is dependent upon; soil conditions (foxtail millet prefers less sandy soils), food grain preferences (pearl millet is considered to "heat" the body, while foxtail millet is a poor man's substitute for rice), safety (pearl millet very rarely fails) and considerations pertaining to rotation (between early sown sorghum and pearl millet and late sown foxtail millet, compare also with Fig. 1). With regard to the wet-land, then the selection of crops depends mostly upon the water level in the tank. If water is available, sugarcane is planted. If it is not, hybrid sorghum is sown.

In this case the agricultural system imposes some restrictions with regard to foodgrains, while the ecological conditions impose many restrictions with regard to cash crop cultivation. So the situation as seen in 1989 appears to be rather constant, which was also confirmed by the survey in 1992.

In 1984, the area under cotton in Mantraghatta was around 30% of total, and it did not become higher in 1989, in spite of the increase in the price of cotton, so this seems to be the maximum value. The proportions between the two food grains finger millet and sorghum remained more or less constant during the period from 1984 to 1989 (see also Table 2), probably because the two crops supplement each other well. Sorghum is thus sown early in the year, while finger millet is planted later (this reduces the risk of complete crop failure, c.p. also the balance between early and late food grains in Thanda, Fig. 1). Sorghum is a little more esteemed as a food grain than finger millet, but its durability is much less. The 1989 situation might thus appear to be rather constant, but in 1992 hybrid maize

replaced nearly the entire area of sorghum, whereas the percentage of cotton and finger millet remained nearly the same as before. This might appear surprising at first sight, but agronomically speaking the change was not so great because maize is sown early, just like sorghum. Possibly the farmers could not afford to increase the cotton area any more due to the heavy investment required, and they had therefore to sow the low input cash crop maize instead. It is not known how the farmers solved the food problem because they do not eat maize themselves. Most probably they had a stock of finger millet from the previous year. The crop composition may return to the 1989 stage if the price of maize falls again.

The crop composition in Bassavangangur is mainly determined by ecological conditions. Thus rice is the most suitable crop on the terraced fields (wet-land) whereas on dry-land finger millet and groundnuts are nearly the only options (along with some tobacco and cotton). The 1989 situation thus seems to be rather stable. The area under groundnuts was, however, unusually large in 1992 (about 35% of the dry-land area), possibly because the irrigation tanks were filled up very soon that year, and the food grains (rice) were thus secured. After all, it seems that this village has also reached a relatively stable level in its crop composition.

It can thus be concluded that the development in crop composition has now reached a relatively constant stage in all four sample villages. All four villages are influenced by ecological and economic factors. However, in Thanda and Bassavangangur, the severe climate means that ecological factors dominate, whereas in Thimmapur and Mantraghatta economic factors become more important, although the farmers are still exposed to some ecological risk if they invest in heavy input cash crops such as cotton or the potato and the rains fail.

Fig. 1 shows the timing of various crops related to the average rainfall pattern. It appears that the peak loads in the agricultural works have by now been well levelled out, so for this reason there is no need for any new crops.

Changes in crop composition might sometimes affect the intercrops associated with the main crops. The decrease in the area under redgram in Thimmapur was, as mentioned, compensated by an increase in the area under greengram and the cowpea, but in other cases the effect might be more serious. Sometimes the new crops introduced cannot have intercrops; cotton does not grow well with intercrops on red soils because they obstruct interculture (on black soil the weed stress is less). The case is the same for the potato and maize. Sometimes the old varieties of intercrop do not go well with the new food grain varieties of shorter duration. Thus the fieldbean has often been abandoned as an intercrop with finger millet because it remains unprotected against stray cattle after the harvest of the main crop. Table 4 also indicates how much intercrop and mixed crop still remain in the four sample villages. The percentages indicate the surface area corresponding to the volume occupied by the roots of the particular intercrop (the leaves often spread out over a much bigger area after the harvest of the main crop). The percentages indicated here are additional (overlapping) to the percentages of Table 3 (so actually the percentages of Table 3 should have been reduced accordingly).

The small and marginal farmers' crop composition has so far not been much different from that of the average farmers'. The areal percentage of cotton was thus nearly the same among bigger and smaller farmers in Mantraghatta (Table 2). (There were actually two types of marginal farmers in that village; one group was more active and rented additional land, cultivated more cotton etc., the other group was more passive, cultivated less demanding crops or mortgaged or rented their land to others.) Furthermore, the marginal farmers in Thanda and Bassavangangur nearly had the same crop composition as others because the selection of crops here depends more upon ecological factors than economic ones. Only in Thimmapur (Table 1, year 1989) did marginal farmers have a slightly different crop composition. The percentage of chillies was thus higher, partly because this is a low input cash crop, partly because it offers the opportunity of using a more intensive labour input (by growing a crop of peas before the main crop and by growing various vegetables and other mixed crops and intercrops). The area under the potato was less than average, because the very high cash input was too risky for the poorest farmers.

For this section it can be concluded that, generally, the agricultural systems have not resisted change so far. The number of livestock and several intercrops were often reduced without regret when cash crops or new high yielding varieties were introduced. Even the marginal farmers have so far been able to introduce the same new crops and practices as others. But it seems that the development (at least in the four sample villages) has now reached a steady state because a further expansion of e.g. cash crops would be economically too risky, mainly due to the unpredictable variations in rainfall. Moreover, the marginal farmers might not be able to follow suit much longer because the number of marginal landholdings is increasing very fast due to subdivision. The sustainability of the agricultural systems is also threatened by the changes which have already happened such as; the increased pesticide stress, dependency upon foreign raw materials for chemical fertilizers, gene erosion and loss of resistance and variation in connection with the introduction of new varieties.

CONCLUSION

The various examples of agricultural development in the four sample villages have shown that the main driving forces behind development have been price incentives (for the expansion of the cash crop area) and new inventions made by e.g. the agricultural sciences. With regard to the expansion of cash crops, it would seem that this development has now reached a certain limit, either because the crops are directly excluded from some areas (ecologically adverse) or due to various risk factors (variable rainfall and prices) in the remaining areas.

So far, the most important innovations for agriculture in this area have been the use of chemical fertilizers and the new crop varieties. There was not so much need for technical innovations as the farmers' own simple implements were quite sufficient. The dosage of chemical fertilizer seems to have reached a certain limit now, at least in the four sample villages, because a further increase would be too risky if the crops fail due to drought or the like. It was relatively easy for the farmers to adopt the mentioned types of innovations, partly because they could make use of already existing practical skills and power of observation, and partly because the agricultural systems did not resist the changes. It is actually still possible to make several immediate improvements in the local use of chemical fertilizers and pesticides by giving the farmers proper information.

With regard to further inventions, plant breeders might still be able to produce many valuable new varieties (e.g. short duration pulses, drought resistant food grains or pest resistant cash crops). New inventions in the field of biotechnology, or the production of biofertilizers and biological means of pest control, are also promising, but would need extension efforts and institutional support from bodies of the same type as The Department of Sericulture. When developing new varieties and methods, scientists should have proper knowledge about the local agricultural systems and their specific needs. Special labour-intensive methods should be developed for the benefit of marginal farmers. According to experience with the introduction of new crops etc. in the four villages, it seems to be particularly important to keep a constant eye on the various ecological constraints, both when new inventions or innovations are being developed, and when they are being propagated to the farmers.

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