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Potentials and Limits of Agricultural Production in Nepal as seen from an Ecological-Geographical Standpoint

Willibald Haffner

With 3 Figures and 1 Table

1. Introduction

In the Himalayas of Nepal, the altitude belt which is put to agricultural use reaches approximately twice the height of that of the Alps, due to the favourable climate of its monsoon tropical location (± 27° northern latitude). Arable farming is carried out from the foreland up to an altitude of over 4000 m. High altitude pasture land for the grazing of yaks can even be found at over 5000 m. Thus the diversity of crops varies accordingly from tropical cereals (rice, millet, maize) and fruit trees at the frost-free, lower altitudes to northern types of cereals and potatoes in the higher mountains (Fig. 1). A correlation of vegetation, climate and land-use will show, that the traditional agriculture in the Nepalese Himalayas has been closely adapted to the climatic conditions and in particular to the turn of the seasons. Thus, the vertical gradation of vegetation and agriculture is astoundingly consistent (Fig. 2). From a climatic viewpoint, an area at medium elevation of between approximately 1300 and 2800 m above sea-level would appear to be particularly favourable, as this altitude belt is suitable for rain-fed agriculture the whole year round, an exceptional case in these monsoonal tropics of seasonal change in climatic humidity. In contrast Himalayan valleys, deeply incised into the mountains and the mountain foreland (below 1300 m) are too dry for rain-fed agriculture in 'winter' and the high-altitude valleys at above 3000 m are too cold (HAFFNER, 1979).

For centuries, the efforts of the Nepalese to wring a living from their mountainous land by means of terrace construction, irrigation channels, the building of bridges and coolie tracks trough malaria-infested valleys and over high, snowy passes were at least adequately rewarded with success. The manifestation of this perfected Nepalese high altitude and mountain farming is, after all, the rotation systems and complicated forms of pasturalism for which the whole of the Himalayas have become renowned. To sum up, the use or rather exploitation of natural resources was developed to perfection by means of the labour-intensive facilities of a pre-industrial society. This made a rural population density of up to 100 inhabitants per square kilometer possible even in the mountains. However, it would now seem that a basic change is occurring, as the population of Nepal has doubled during the last 20 years. As in neighbouring India and Tibet, it is the successful eradication of disease (e. g. malaria, small-pox and cholera) and general improvements in hygiene and medicine which are mainly responsible for the tremendous increase in population from c. 7 million inhabitants in 1963 to c. 15 million in 1983 (cf. Table 1).

As in many other high mountainous regions, a main characteristic is the exceedingly unbalanced distribution and development of the population: extremely densely populated agricultural areas exist alongside almost uninhabited stretches of forest and high mountain regions (cf. Fig. 3). All in all, the population growth has been approaching a critical threshold during the last decade; indeed it may have already crossed it. The daily, per capita, calory consumption already lies on average below 2000 calories (cp. Switzerland: 3240 cals.). Above all towards the end of the dry season when the stores from the previous year are all used up and the new harvest has not yet been brought in, only one meal a day is eaten.

The question is, what can be said from an ecological-geographical point of view to the incongruity between population and agricultural production which is increasing from day to day? Is it actually possible to increase agricultural production or is the 'agri-potential' of the land already exhausted?

It is possible to simplify and reduce the problem of increasing agricultural production in an attempt to answer the following three questions:

1. Is it possible to extend the area of agricultural acreage in Nepal?
2. Can the harvest area still be enlarged?
3. Is an increase in yield per hectare possible?

In attempting to answer these questions, which are so elementary for the planning of land-use in Nepal, one must, however, accept one basic restriction. Plans for improvements should not be based on the idea of an increase in production, of growth at all costs. Too much has been reported during the last two decades of forest decimation and soil erosion, of ecological damage caused by agricultural overutilization (see, for example, KIENHOLZ et al., 1982). On no account should the ruthless exhaustion of natural resources be propagated. The absolute aim should be an increase of agricultural production using ecologically tolerable methods.

In pursuing this aim, ecological and plant-geographical observations and investigations can play an important role in compliance with the much-quoted principle which states, that the collective manifestation of ecological conditions of a certain location, and thus also that of its agricultural potential, may be observed in its vegetation. Furthermore, the ecophysiological cycle of functions and the ecological stability of autochthonous natural or seminatural ecosystems (e. g. forest ecotopes in natural forested areas) can furnish us with patterns for at least sufficiently stable agricultural ecosystems and the development of ecologically adapted types of agricultural land-usage.

HUECK (1953) sets a similar aim in his treatise: "Urlandschaft, Raublandschaft und Kulturlandschaft in der Provinz Tucumán im nordwestlichen Argentinien". The "appropriate creation of a healthy agricultural landscape" (LAUER, 1956, p. 12) is the main aim in LAUER's work "Vegetation, Landnutzung und Agrarpotential in El Salvador". The longterm protection of our natural environment and its resources is, after all, the aim of the concept of ecological farming as propagated by EGGER (1982); retention and increase of the "humane-ecological capacity" is the content of V. MAYDELL's (1982) agroforestry concept.

2. Expansion of the Agricultural Acreage in the Remaining Forest Belts of Nepal: Possibilities and Limits

The main ecological factor for the almost complete retention of the belt of forest in the Bhabar Zone and the Churia mountains is the shortage of surface water throughout the year. The relief of the two areas is different but the geological subsoil in both consists to a large extent of coarse, young gravel (Upper Siwaliks) and is thus so porous, that even during the monsoon season, the rivers (except for a few allogenous ones) only contain water episodically (after heavy rain), although there is annual rainfall of about 2000 mm.

Besides the unfavourable geoecological factors which have hindered an extensive colonization of the Bharbar and Churia regions, strategic and political reasons also played a decisive role for Nepal in retaining these forest landscapes. Nepalese kings and rulers were well aware of the value of this fever-infested southern border, difficult to traverse, as a buffer zone between them and the British Colonial Empire. It was this belt of forest which made Nepal's policy of isolation possible, which lasted for over a century until 1951. In particular, following the compromise peace of Sagauli in 1814 between Nepal and the British colonial forces in India, strict forestry protection laws came into being, which not only forbade the clearing of forests and the laying out of settlements and fields, but also even the scattered use of these forested areas (REGMI, 1963, p. 37). The protection of the forests in the Nepalese lowlands was also in the interest of the ruling feudal upper-class, as they were thus provided with one of their best big-game hunting areas (elephants, tigers, wild buffalo, rhinoceros etc.). Although the scarcity of surface water and springs, i. e. of drinking water, did complicate and actually hinder colonization, the porosity of the subsoil is compensated for by rainfall of roughly 2000 mm, as the lush Sal Forest shows. This same Sal

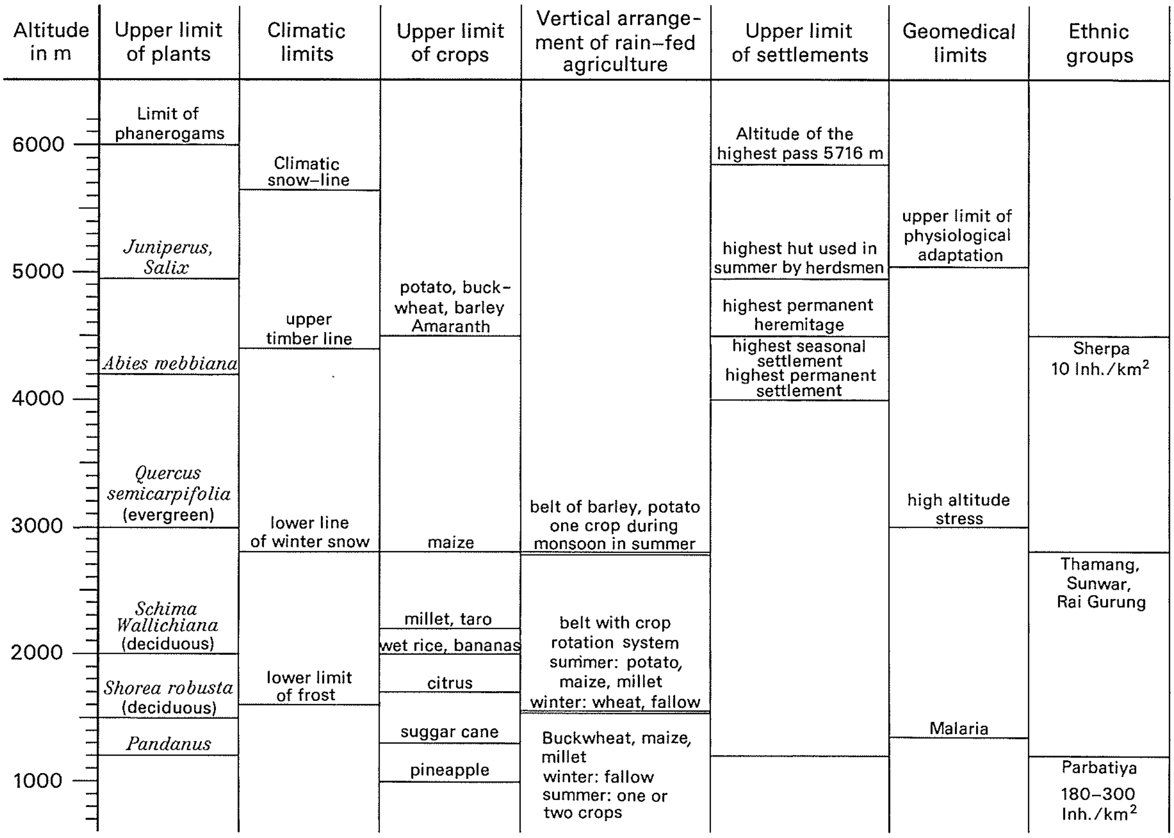

Fig. 1. Altitudinal Belts and Limits in the Himalayas of Nepal – Correlation of Vegetation, Climate and Land-use.

Forest is also perfectly adapted to the seasonal cycle of rain and dry spells. It is a timber forest consisting of thickets of deciduous trees with a closed canopy of foliage. Leaves fall at the height of the dry season from March to May. Characteristic for the rainy season is the lush ground vegetation of shrubs and grasses, which are only able to survive the unfavourable season of the year in their seed state or just with their subterranean parts like roots, rhizomes etc.

What could be more natural than to assume, that all that is needed to create extensive areas suitable for farming in the rainy season, is the axe-bearing hand of man to clear the forest? It will, therefore, come as a surprise to learn, that maize and millet suffer from lack of water here in spite of heavy monsoon rainfall. Maize begins to wilt and problems with water provision occur even in short dry periods of about 10 days during a break in the monsoon; a period in which the neighbouring Sal Forest continues to flourish. Several factors are to blame for this incongruous state of affairs.

We need not go into details here about the fact that trees and bushes flourish here. Their roots go much deeper than the quick-growing, annual crops and also have a greater potential for water retention. Ecologically speaking, the above-mentioned crops cannot be compared to forest trees; rather they are compatible to the undergrowth of shrubs and, above all, grasses, i. e. plants with the same or a similar form of life.

As far as the amount of water available is concerned, the conditions for growth on a maize field and in the undergrowth of a forest vary greatly. The soil erosion in a freshly ploughed maize field caused by only a short period of heavy rain will suffice to considerably reduce the potentiality of the soil layer for water retention. A further factor is the relatively high loss of water from the soil of a maize field due to direct evaporation from the unprotected surface, whereas in the forest, desiccation of the surface soil layers is greatly arrested by the permanent shade.

Vegetation	Agriculture	Pasturalism
Alpine meadows/Tibetan steppe of high altitude valleys ca. 3700–5000 m t > 10 °C: 0–2 months leeward location: N < 1000 mm dry and cold winters, very often snowfree	rainfed agriculture during summer (potatoes, buckwheat), partly by additional irrigation (barley), intensive agriculture with high input of dung	dominating: permanent grazing on high altitude meadows, hay production, shortage of fodder during the dry season and in snowy winters
Rhododendron-Abies-forest ca. 2800–4000 m t > 10 °C: 4–8 months frost luvward location: N > 2000 mm often > 3000 mm altitude of maximal humidity March–November: extremely cloudy and misty snowcover in winter	potato cultivation in forest clearings	dominating: permanent extensive grazing shortage of fodder in snowy winter no hay production cheese dairies
Tropical evergreen mountain and cloud forest ca. 1300–2800 m t > 10 °C: 8–11 months from 1500 m onward frost free of Malaria luvward location: N > 2000 mm altitude of maximal precipitation short dry season: Nov.–Febr. high edaphic humidity caused by long rainy season and diminished evapo-transpiration	dominating: permanent rain-fed agriculture summer: rice (up to 2000 m), maize, millet winter: winter corn, potatoes	permanent grazing: goat, sheep, cows, water buffalo forest meadow pruned fodder shortage of fodder from Dec.–April
Tropical deciduous forest; dry and moist Sal Forest ca. 100–1300 m t > 10 °C: 11–12 months Malaria free of frost, temperature no limiting factor long dry season from Dec.–June shortage of drinking water N < 1500 mm	dominating: rainfed agriculture: rice, maize, wheat, mustard fields seasonal fallow during dry season local: permanent agriculture with irrigation	cow, water buffalo, goat grazing on fallow fields no fodder storage

Fig. 2. Altitudinal Arrangement of Vegetation, Agriculture and Pasturalism.

In the ecosystem of, say, a Sal Forest, water is mainly lost by evaporation from the surface of the leaves especially from the upper foliage and by way of transpiration. Of vital importance is also the fact that the level of air-humidity in the interior of a forest is higher than that existing in an open field, thus, evapo-transpiration is decreased to a relatively large degree and survival of short, dry periods is facilitated even for hygrophile plants.

One can also clearly see the extent to which the undergrowth has adapted to the particular climatic conditions peculiar to the confines of this forest in the fact, that at the onset of the rainy season, a closed canopy of foliage first developes in the upper tree layer before the growth of the underlying vegetation begins. If the covering of trees were to be removed, the layers of shrubs and grasses would dry out and decay after only a few days of sun. During the dry season in winter, the compensating effect of the forest and its particular climate on the amount of water in the Sal Forest ecosystem can be seen very clearly. The water retained in the soil from the monsoon period will last for months under cover of the foliage (shade). The Sal Forest is of a fresh, green colour even in December and January, whilst farming at this time is only worthwhile in the fields of the Terai if artificial irrigation is employed.

Which conclusions may be drawn to be of profit to agriculture from the above partial analysis of a Sal Forest-type ecosystem?

1. From an ecological point of view, the cultivation of perennial tree crops in the edaphic dry Bhabar Zone must prove to be more successful than the cultivation of annual crops. That is unless
2. we cultivate annual crops (maize and millet) underneath the protective foliage canopy of the trees. Furthermore, a combination of forest and agricultural farming would reduce the loss of essential forest resources.
3. Finally, the water problem could be solved by the construction of irrigation canals. The water for these could be obtained from the few allogenous rivers or from deep wells.

Recent colonization and irrigation projects in the Bhabar Zone of Kumaon could serve as models. However, Nepal is so far lacking in both the technical and financial means for large irrigation projects, which require a great deal of capital. It seems to me that it would be more realistic to experiment with combined forest and conventional farming. Methods of agro-forestry are traditionally known in the Nepal Himalayas, especially in areas where a combination of annual crops and fodder trees is grown.

The question of why the Rhododendron and Fir-wood belt (2900–3700 m) is not perennially settled but used only for extensive grazing, is not easy to answer. It is true that podzolized, infertile soil and slight frost and snow in winter are characteristic for this Fir-forest belt, but from an ecological point of view the cultivation of northern types of cereal, of buckwheat and potatoes is not hampered by such a winter, which, compared to that of Europe, is mild. As Nepalese farmers themselves will stress, the qualitatively best potatoes are even grown at this altitude. Hence, the Himalayas of Nepal are no exception from the rule which generally applies to the tropics and subtropics, i. e. that humid mountain forests with plenty of cloud and mist are avoided in the choice of locations for permanent settlements. Here one can quote examples from South American Andes and Africa (Kilimanjaro). Although I cannot provide an absolutely satisfactory explanation for the lack of permanent settlements in the Fir-belt of Nepal, the following reasons would seem to me to be important and also plausible from the point of view of the Nepalese mountain peoples:

1. Storage of cereals etc. is almost impossible in the particularly cloudy and damp climate of the monsoon summer. Anyone who has travelled at these altitudes during the rainy season will know how quickly clothing, blankets and household implements of all kinds attract the dampness, go mouldy and decay.
2. Many types of crop (e. g. the spices, fruit and vegetables so prized by the Nepalese, and in particular maize and rice) do not flourish at this altitude as a result of summer temperatures being too low. Therefore the limit to the altitude at which permanent settlements are built, especially those of the Indian- and Hindu-influenced cultural groups, more or less corresponds to the upper limit of maize and millet cultivation. Potatoes and northern types of cereal are simply alternative products, according to traditional eating habits of these ethnic groups.

Thus, the real reasons for the lack of settlements so far in the humid Fir-belt should be sought in ethnic traditions; climatically speaking, the upper limit of cultivation and perennial settlements has not yet been reached in the Nepalese Himalayas.

However, a warning must be issued here, that extensive clearing activities would be unwise for geo-ecological reasons, even if the increase in population density in the lower-lying, main settlement areas would seem to make this unavoidable. This cloudy, misty Fir-belt is actually the natural reservoir for the drinking and irrigation water needed by the so densely populated lower altitudinal belts. It is the only source of the perennial rivers (if one disregards the even higher mountain belts) and in particular of very many mountain rivulets and springs. Thus, one cannot emphasize enough the danger of incorporating this forest belt, which has so far merely been used for extensive grazing purposes, into the lower-lying, densely populated and intensively farmed areas. Forest clearance also does nothing to increase the amount of cattle feed available. An analysis of the plant-succession following clearance and burning of the trees will show that it is rather the opposite which occurs. The cattle refuse the types of plant which are then dominant (*Arundinaria*-Bamboo, *Berberis, Euphorbia, Cotoneaster* and Ericaceas).

To sum up we must bear in mind, that an extension of the settlement and agriculturally used areas in the region of the great forest belts of Nepal would, from an ecological standpoint, indeed be possible, i. e. seen from this angle the agricultural potential of the land is by no means exhausted. However, one should caution against areal development of the forest belt in order not to disturb the balance of the supply of water from the Rhododendron and Fir-tree belt and, as far as the irrigation projects in the Sal Forest belt are concerned, for reasons of profitability. Combined traditional and agro-forest farming seems to have potential here. In practice this means that peripheral extension of the main, intensively farmed agricultural area of Nepal can only be partially advocated from the planners point of view, at least at the present time. Thus, as far as an increase in agricultural production is concerned, the densely populated areas of Nepal, the Terai and the Lower Himalayas, gain in central importance (Fig. 3).

The Terai has been forest-free agricultural land for centuries now. Even in the area of the Lower Himalayas all the land has been carefully terraced and cultivated for generations, as far as local relief and soil conditions permit. An extension of the agriculturally used area is therefore out of the question. All the more important then, would seem to be the question of increase the degree of intensity, with which the land is farmed. During the winter dry season, 90% of the monsoonal rice and maize fields lie fallow, both in the Terai and the densely populated valley belt of the mountains. With winter rainfall of less than 100 mm, the fields remain uncultivated due to scarcity of moisture. It would therefore seem a good idea to compensate for the lack of rainfall with the aid of irrigation and thus to considerably extend the double or multiple cropped area. This should certainly be feasible in the Terai even without much technical effort. Although most of the channels are seasonally dry, the ground water remains close to the surface all the year round. Even at the height of the dry season an adequate amount remains available in the drinking water wells and it is only necessary to excavate tub-like holes in the dried-up river beds for the water buffalo to be able to wallow there.

Thus the supply of ground water definitely allows for cultivation of the fields in the dry seasons and one must ask oneself why water is not supplied to the fields by means of simple pumps, as it is the case in other parts of India. Probably the main reason for this is, that the main harvest during the rainy season is seldom threatened by lack of moisture. Often the exact opposite is the case, and the level of the ground water is too high. In spite of high population density, the Terai has so far always produced a surplus of grain, ensuring the supply of basic foodstuffs. Why then, should there be wells and canal systems exclusively for

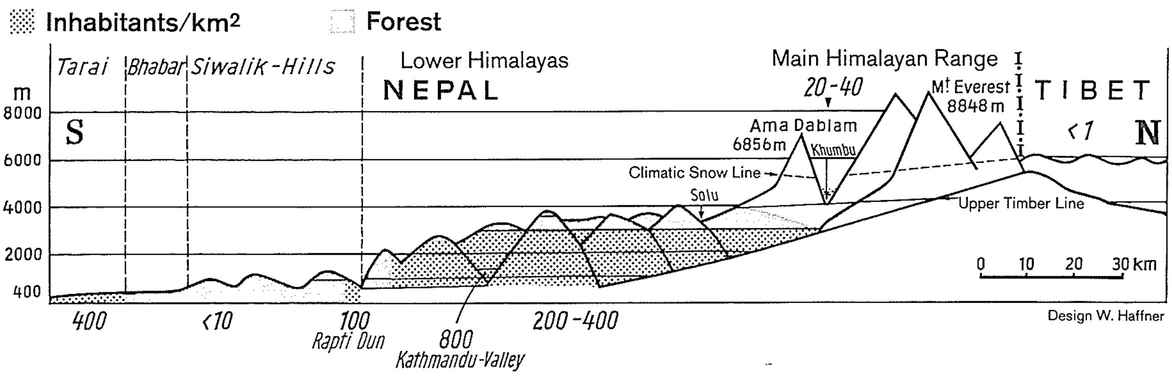

Fig. 3. Nepal Himalaya: Forest Distribution and Population Density in Profile.

Table 1. Population Density and Growth by Region in Nepal.

	Population 1971	Population density Inh./km² (1971)	Population 1981	Population density Inh./km² (1981)	Decennial growth of population	Growth in %
Nepal	11 555 983	80	15 021 460	103	3 464 469	+ 30,0
Terai	4 403 378	129	6 559 525	192	2 156 147	+ 49,0
Hill	5 997 642	98	7 170 853	117	1 173 211	+ 19,6
Mountain	1 154 963	23	1 291 082	26	136 119	+ 11,8
Eastern Dev. Region	2 797 500	100	3 703 848	132	906 348	+32,4
Terai	1 387 558	196	2 115 220	299	727 662	+ 52,4
Hill	1 105 590	88	1 254 787	100	149 197	+ 13,5
Mountain	304 352	36	333 841	39	29 489	+ 9,7
Kathmandu Valley	618 911	650	766 820	805	147 909	+ 23,9
Chitwan	183 644	74	257 332	103	73 688	+ 40,1

farming in the dry season? Furthermore, the farmers also need the stubble fields as they have no system of fodder storage for the cattle. Finally, allowing the field to lie fallow improves the soil fertility, which is particularly important for the cultivation of rice, as rice fields are seldom fertilized. The cycle of rainy season cultivation and fallow land in the dry season constituted a system of farming, which was adapted to climatic conditions and which was at the same time suited to the traditional population density. However, since the successful eradication of malaria during recent years, population density has increased extremely rapidly (Tab. 1). This is the reason why the traditional agricultural system should be abandoned in favour of permanent cultivation (multiple cropping) based on artificial irrigation. Hydrological and climatic requirements are fulfilled.

In the mountainous areas, the prospects for extending the double or multiple cropped area at the cost of land lying seasonal fallow (which, as in the Terai, includes almost the whole of the summer rice and maize fields), are however, considerably less favourable. Ground water can only seldom be used for irrigation, at the most only at the bottom of the valleys. Most mountain streams and springs periodically run dry or fluctuate so greatly in the amount of water they contain, that, although they are useful in irrigating the wet rice fields during the rainy season, they are out of the question for dry season irrigation of, say, wheat or potato fields.

Irrigation water can thus only be drawn from the few perennial rivers, the sources of which lie in the Rhododendron and Fir-tree belt or in the high mountains. However, the traditional methods of canal construction are technically incapable of conveying water for irrigation from the often deeply incised river beds onto the level of the areas to be fed. It is technically possible to pump river water up to fallow mountain slopes and on up to the ridges, but the question of profitability immediately arises. It is therefore impossible to extend the multiple cropped area by ⅔ or more in the mountains, as would seem to be a plausible prospect in the Terai. It then becomes even more important to utilize the last reserves of potential irrigation water.

In some of the smaller lateral valleys with perennial river water it would be quite feasible to channel off water for irrigation purposes on the upper course by constructing a sloping canal. However, such projects would be of a scale hardly possible for a single village to undertake.[1] Irrigation of the alluvial fans provides further opportunities of extending permanent farming of irrigated fields. It would be possible to prevent most of the water oozing away by lining the canals with plastic sheeting and that at very little cost. Using this method one could also tap the overflow of certain drinking water wells for the cultivation of vegetables in winter. Even so, the very limited opportunities for expanding the irrigated fields, farming of

[1] Example: The Khate Khola Canal: 8 km, 1 m Ø, 4 million Rs = 260 ha. Relatively not very effective, although large amounts of capital invested.

mountain valleys in the dry season provide a challenge to search for other ways of extending the multiple cropped area at the cost of seasonal fallow fields.

Here too, we can be aided by a comparison with the natural vegetation. I have already pointed out in the example of the Bhabar Zone, that deciduous trees typical of this location can retain their leaves for a period of months during the onset of the dry season, due to the fact that sufficient ground water is still available, left over from the monsoon. This edaphic moisture, retained from the monsoon season, has so far rarely been exploited for agricultural purposes. It is true that the soil layer of a fallow field dries out much quicker than the shaded ground in a forest, but the remaining moisture, in particular in the soil of wet rice fields after the harvest, is so considerable that weeds appear and dropped grains of rice begin to sprout only a few days after the crop has been gathered in. Should a last monsoon shower fall and if the cattle are kept away, the stubble field will be covered with a carpet of green in a matter of weeks. There is usually even enough moisture for weeds to reach the seed stage, proof of the fact that plants for cattle feed can be cultivated here, but only of those types with the same ecological requirements as the weeds.

Which plants should be considered then for cultivation? I would suggest both northern cereals and fodder plants, in particular certain Leguminosae, e. g. *Trifolium subterraneum, Medicago* and *Stylosanthes* strains, for their pronounced resistance to aridity and their high protein content. This would more than compensate for the loss of fallow land. Finally, the Leguminosae, with their capacity for soil improvement, would to a certain extent provide an alternative to soil regeneration by laying the land fallow. In conclusion, I would like to point out one problem. It may be assumed, that it is possible to reach a sufficiently satisfactory level of feed production even in extremely dry years. The production of seeds, however, always constitutes a risk. In summing up, the following main points should be observed: the introduction of the previously unknown fodder cultivation and the fact that Leguminosae as a post-monsoon crop are, ecologically speaking, quite feasible. The multiple cropped areas could thus be considerably enlarged and a main evil of cattle breeding, i. e. the chronic shortage of fodder during the dry season, would ultimately be removed.

3. Increase of Agricultural Production by Means of Improvement of Areal Yield

Yield in agriculture has been levelling out over centuries now at a low level typical for Southern Asia: rice ± 20 dz/ha, maize 18–20 dz/ha, winter grain crops are only 10 dz/ha. The productivity is also extremely low on the pasture land. The obstacles which lie in the way of an increase in yield can best be drastically illustrated in the example of this pasture land. An analysis of meadow vegetation will support this.

Present-day pastures are exclusively made up of former forest land on slopes which are too steep for terraced cultivation. Permanent farming, the pruning of deciduous trees, the occasional burning of forested slopes, removal of firewood, soil erosion which accompanies the degradation of the trees etc.; all these factors have contributed to the natural selection of a type of plants which can endure being torn off and trodden down by cattle, regular burning and edaphic aridity, and can survive on a low level of soil fertility. This process of natural selection can go so far as to reach a state where only certain strains remain which the cattle refuse to eat, e. g. Ericaceas, Lauraceas and thorny *Berberis* species, herbs like primulas, *Euphorbia* and *Anaphalis* in the undergrowth. This extreme state of natural selection has already been reached in many cases in the tree and shrub layers.

Which methods of pasture improvement can be implemented at all under such unfavourable conditions? The first step should aim at the reduction of the number of cattle per area unit and a limit to the time they spend grazing there. This should at least put a stop to the continual, steady degradation of pasture land. That in itself would be a considerable step in the right direction. However, this is only possible, if the time spent by the cattle in the pastures could at least partially be compensated for by the introduction of fodder cultivation. At present this remains quite a theoretical demand.

One means of improving the pastures could be to fertilize some of the smaller meadows and to sow more productive grasses and types of clover there. As can be seen in the example of the Sherpa summer settlements in the high mountains, and even under Nepalese seasonal dry climatic conditions, the typical lush meadows only come into being if regularly manured. However, in future, the dung available in the lower-lying regions will remain destined exclusively for the cultivated fields, i. e. for the cultivation of basic foodstuffs and not that of fodder.

In my experience, the most promising course of action would seem to be the cultivation or rather the attentive care of fodder trees in so-called 'fodder orchards'. Such fodder orchards can regularly be found in certain valleys of East and Central Nepal. The leaves of the trees are removed but never so many as to kill the tree off. The planting of trees for this purpose is an example of the best possible sort of fodder storage for the dry season. There are few ecological problems involved in planting fodder orchards on degraded pasture land, if local types of tree, adapted to the terrain, are used. In many cases one could even fall back on the remains of forests and protect and spare the trees for a time from further tearing off by cattle, too much leaf pruning and so on. It is not the ecological reasons which are to blame for being an obstacle to the further expansion of fodder orchards, but claims to land ownership. Pasture land is almost always common land or in the hands of the state. Therefore farmers collect leaves and chop wood as they think best and necessity dictates. On the other hand, well cared for fodder orchards are always privately owned.

A little more optimism would be appropriate in the following discussion of an increase in the yield in agriculture, but even in this field there are many-sided problems which have not all been recognized as yet. It is a fact, that the yield per acre cannot be increased by further mobilization of labour. An increase of agricultural yield with the aim of an adequate level of self-subsistance amongst the population can thus only be achieved by the concentrated implementation of yield-improving capital intensive methods. This would essentially mean the use of chemical fertilizer and improved seeds. With the introduction of improved seeds of the so-called high-yield varieties we would then be confronted with a key ecological problem. These varieties of grains which have so far been grown have not only adapted themselves to the seasonal cycle of rainy and dry seasons, but also to the length of the day, the acidic soil, low soil fertility and, last not least, to traditional methods of cultivation. We can paraphrase this by saying that the autochthonous strains fit in with the ecosystem. Interference with this established system by, for instance, spreading chemical fertilizer or sowing new types of seed, results in often rather unpleasant surprise. For example, the reaction of local strains of wheat even to large amounts of chemical fertilizer is often negligible. Local varieties are bad convertors of fertilizer. If one spreads chemical fertilizer on certain local strains of rice, they will develop a long, fragile stem and tend to hang their heads. The grain yield, however, is not increased. Swiss farmers have experimented with European, high-yield varieties of cereal. The harvest was satisfactory but these varieties ripened during the monsoon. High-yield strains of Mexican wheat, which were further developed in Northern India, are well adapted to the seasonal cycle. Sometimes it is possible to more than double the amount produced per hectare with these high-yield varieties, but only if large amounts of chemical fertilizers are applied and water for irrigation is supplied in plenty. The results of experiments with high-yield rice varieties from Japan and the Phillipines have not always been satisfactory. In particular the constant level of water in the fields which is required by these types can only be maintained to a certain extent in Nepal, with its typical systems of canal irrigation and collection of rain water.

The extremely specific ecological conditions required by the high-yield rice varieties are even more difficult to fulfil than, say, those of wheat. If errors are made when sowing the fields or in irrigation, the yield may drop considerably below that of local types. Thus, some farmers have fallen back on traditional, local strains, which produce a lower but relatively constant, risk-free yield.

Finally, if we ask ourselves where one could most effectively employ such methods of yield improvement as chemical fertilizer and improved seeds, the answer must be in the areas of the Terai which are opened up to traffic. During the dry season, irrigated farming could be considerably expanded. The greatest successes on record so far in Northern India have been with regular irrigation, ample supplies of chemical fertilizer and use of high-yield varieties. However, we are still a long way from a "green revolution". Which suitable solution can be put forward for the densely populated mountain regions and for settled valleys with up to 400 inhabitants per km^2?

Methods of yield improvement and therefore of saving land which require large capital investment are certainly not unknown. However, there are local disadvantages (relief, lack of roads and means of transport), which, together with the chronic lack of capital of the small to minute farm units, either delay or prevent entirely the introduction of technical innovations in the agricultural field. In certain Himalayan valleys which are sufficiently open to traffic, e. g. in some parts of the Kathmandu Valley (MÜLLER, 1982 and 1984), the use of mineral fertilizer, insecticide etc. is quite normal and profitable, in particular in the production of cash crops (e. g. seed-potatoes and vegetables, but also of rice). In some cases it has proved possible to considerably increase the yield per acre, especially in those areas influenced by projects set up by the Agricultural Advisory Service.

The increase of productivity in the cultivation of crops in remote mountain regions where cereal farming is practised (maize, wheat, millet and rice) and which have a capital-extensive, self-sufficient economy, can only be conceivable, if alternative agricultural methods are applied, based on the use and further development of autochthonous, labour-intensive techniques and a greatly increased use of humus (see EGGER, 1982). Of course, the techniques of ecofarming have yet to mature in many ways. In particular there is a great lack of experience of local conditions. Critics stress the fact that there is not enough definite data on yield, ultimately there is no information on profitability. At the present time there remains only one course of action for the majority of small farms and those which have been even further reduced by the population explosion and land inheritance laws to take in order to increase production, i. e. the expansion of the agriculturally used area. With the population steadily increasing, there is usually plenty of labour available. The clearance of bush forests and pasture land, already often greatly degraded by the removal of firewood and fodder and the advance of cultivated fields on to much too steep slopes, which in the long run prove to be unsuitable, i. e. into typical areas of marginal yield, are to blame for those irreversible, morphodynamic processes, beginning with scarcely visible soil erosion and often ending in land slides of catastrophic dimensions. However, we should not allow ourselves to believe, that this negative development has remained unnoticed by the mountain farming population, with their rich, traditional store of experience. In view of the limited opportunities available to them, they know of no other alternative but to move to the mountain foreland, overpopulated as it is.

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