6.2 Low – input farming

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6.2.1 Introduction

Up to this point in the monograph only those production situations have been presented where crop growth was determined by a limited number of well – defined factors that could be at sub – optimal levels. The hierarchical models presented describe methods for a quantitative estimation of possible yield levels under well – defined conditions. In agricultural systems where land and labour are the predominant inputs, the conditions are less well – defined. In such low – input systems it is practically impossible to estimate yield in similar ways, because of lack of knowledge. A general treatment therefore must proceed along different lines.

A main characteristic of low – input farming systems is the emphasis on production of basic needs, in particular food, by a farm family using its own labour, possibly supplemented by animal traction. For a family to subsist, the yield of the agricultural land has to be sufficiently large. Therefore in many low – input agricultural systems, relations can be recognized between the size of a family, the number of draught animals, the soil fertility, the yield and the cultivated acreage. Some of these relations will be discussed in this section.

6.2.2 Basic needs

In most low – input farming systems a family is primarily growing crops to satisfy its basic needs. Today it rarely occurs that all basic needs for food, clothing, shelter, heating and social activities are produced or gathered within the framework of small communities. Subsistence farming refers, therefore, in general to the situation where self – sufficiency in food, fuel and shelter exists, and if possible part of the harvest is marketed to enable the purchase of other necessities: clothing, education, health care, to mention a few. As the emphasis is on food subsistence, the family does not aim at yields that are as high as possible under the prevailing environmental conditions, but rather at maintaining a production level that is high enough to cover food needs and keeps the risk of crop failure to a minimum. In that situation, the first question that arises is how much food is required for the family, and the second one, how it can be produced.

How much food is required depends on the size of the family and its composition in terms of age, sex and body weight, and the activities in which it is engaged (Figure 56). Although minerals, vitamins and proteins are indispensable, they constitute only a minor part of the total food requirements. Most

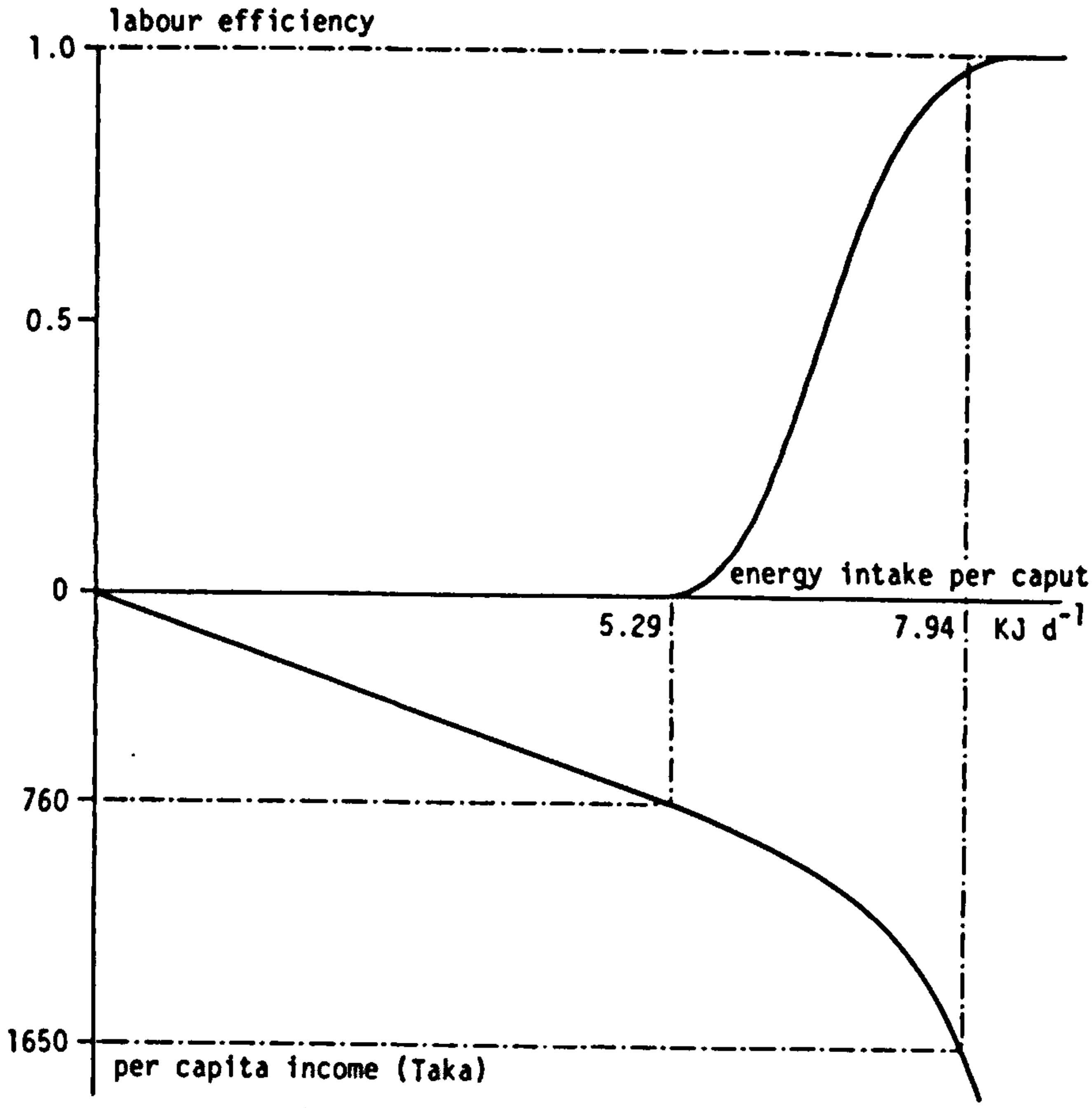

Figure 56. The relation between income, energy intake and labour efficiency. Estimates based on the Bangladesh Household survey; adapted from Stolwijk (1983).

food norms are based therefore on energy demand, assuming that if the energy demand is met shortages of minerals, vitamins, proteins and other nutrients will not occur. The energy requirement is usually expressed in Joules per kilogram of body weight, to account for differences in age and sex. For an average family, consisting of three adults and three children, with an average energy requirement of 8.4 MJ per day, the annual energy requirement is about 18.5 GJ. The energy content of rough rice at a moisture content of 0.1 kg kg^{-1} is 15.5 MJ per kg. If this is the main food, this family of six members needs about 1200 kg yr^{-1} for consumption. Allowing for preparation losses of 10%, pounding losses of 20% and harvest and storage losses of 15%, 1950 kg of paddy has to be produced. If it is assumed that an excess of 30% has to be produced to meet other basic needs and to buffer against the risk of crop failure, the total production requirement will be 2500 kg of paddy per family per year. Whether this is sufficient, depends on market conditions and on what basic needs are considered.

The production target of 2500 kg of paddy per year in a low – input system can be achieved with varying areas of land. On rich volcanic soils or on alluvial soils that receive an annual supply of nutrients through silt in irrigation water, that yield may be harvested from less than one hectare. On most soils, however, yields will be much lower, consequently a farmer has to cultivate more than one hectare to reach that production. It should also be taken into account that the necessary sowing seed, about 60 kg ha^{-1}, has to be withheld for the next year.This comprises only 2.4 % of the yield at a yield level of 2500 kg ha^{-1}, but already 24 % at a level of 250 kg ha^{-1}. Therefore, at low yields a considerable area is necessary to meet the production target. In Figure 57 the relation between yield per area and total area under cultivation is shown for a production target of 2500 kg of paddy.

Exercise 81

The tillering potential of wheat is smaller than that of rice , so that for that crop about 150 kg ha^{-1} sowing seed is needed. Construct a similar graph as the one in Figure 57 for wheat, assuming a production target of 2500 kg per family per year.

If cassava is the staple food, determine the yield that has to be at least maintained to sustain the family (the energy content of the fresh cassava root is 6.0 MJ kg^{-1} and the non – edible fraction is 0.2 kg kg^{-1}).

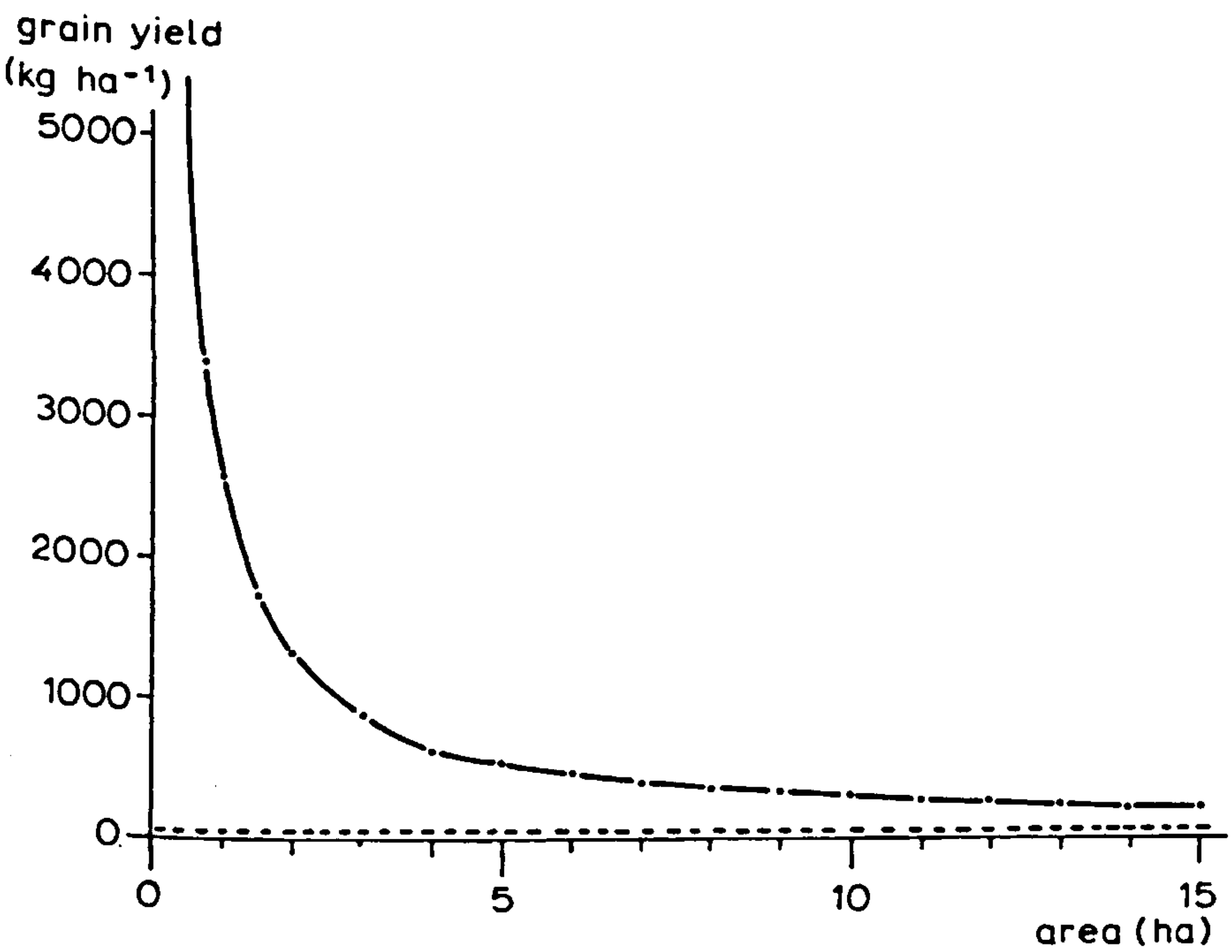

Figure 57. Grain yield required to obtain a production target of 2500 kg paddy from varying areas of crop land. The dotted line represents the amount of sowing seed (60 kg ha^{-1}) that has to be preserved.

A family practicing low – input farming can, however, not extend the cultivated area to an unlimited extent, even if enough land is available, because the maximum area that can be cultivated depends on the availability of labour during periods of peak demand. The required yield level to sustain the family is thus determined by both the cultivable acreage and the total production target. The extent to which actual yields in some low – input agricultural systems differ from these minimum yields will be considered later in this section for some agricultural systems.

6.2.3 Equilibrium yields in agricultural systems

A crop production system in a certain environment submitted to the same cultural practices year after year will eventually reach a state of equilibrium, as is illustrated in Figure 58 for yields of rye in the period from 1880 – 1960. The data are derived from a diluvial, loamy sand soil in Germany receiving an annual precipitation of 500 mm. The year – to – year fluctuations are large, but the trend represented by the eye – fitted curve is evident. That curve could well be described by an exponentially decreasing function of time. However, such a descriptive approach does not explain the dynamic characteristics of equilibrium. What will happen if cultural practices change? How long will it take to reach a new state of equilibrium? What will be the associated yields? Explaining the dynamic properties of equilibrium exhaustively, especially in the context of low – input agriculture, is practically impossible, because too many factors may be involved.

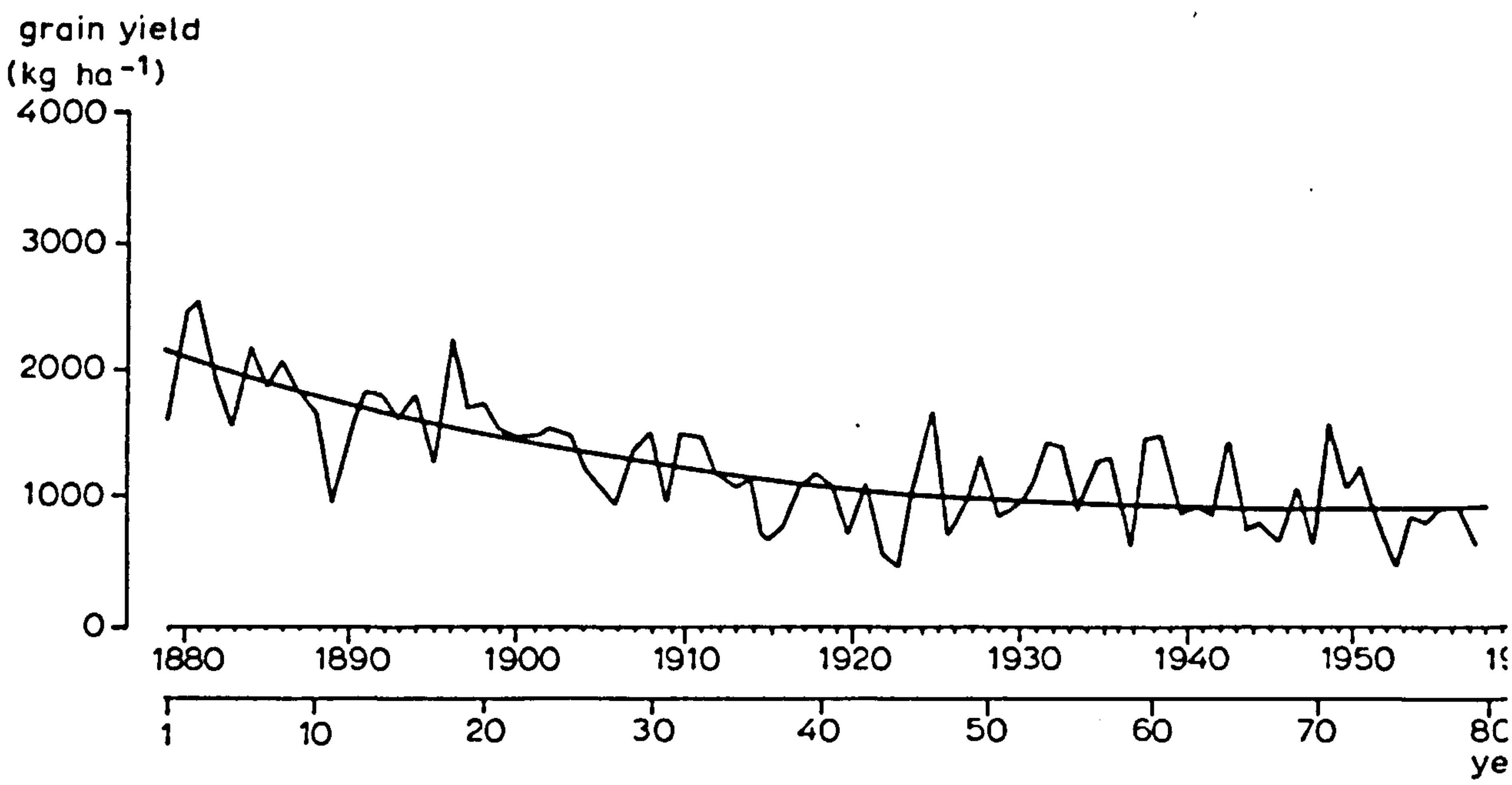

Figure 58. Yield of rye from unfertilized land (adapted from Müller and Reiher, 1966).

Exercise 82
The continuously decreasing line in Figure 58 can be described by an exponential function (Exercise 10) of the form $Y_t = (Y_0 - Y_e)e^{-kt} + Y_e$
What is the meaning of the symbols?
Make rough estimates of Y_0, Y_e and k using the data of Figure 58.

However, simple and general concepts may help to understand the dynamics of the system. One of the earliest concepts was developed by von Wulffen (1823). Although his theory is more than 150 years old it is still worth considering. At that time very little was known about chemical and physical processes involved in plant growth. Therefore the author considered crop yield as a function of the 'Reichtum' (literally: richness, fertility) of the soil which was expressed in the same units as crop yield. A fertility of 20000 kg of rye per hectare means that in total sufficient nutrients are available to produce 20000 kg of this crop from one hectare in the course of time. A single crop cannot extract all fertility in one season. Therefore the 'Tätigkeit' (literally: activity, availability coefficient) was defined as the proportion of the total fertility transferred to crop yield in one cycle. Hypothetically, with an initial fertility, R_n, of 10000 kg of paddy and an activity, T_c, of 0.1, a yield, Y_n, of 1000 kg of paddy would be produced the first year and the fertility next year, R_{n+1}, would be 9000 kg paddy. This can be expressed as:

$$Y_n = R_n \cdot T_c \qquad (95)$$

$$R_{n+1} = R_n - R_n \cdot T_c \qquad (96)$$

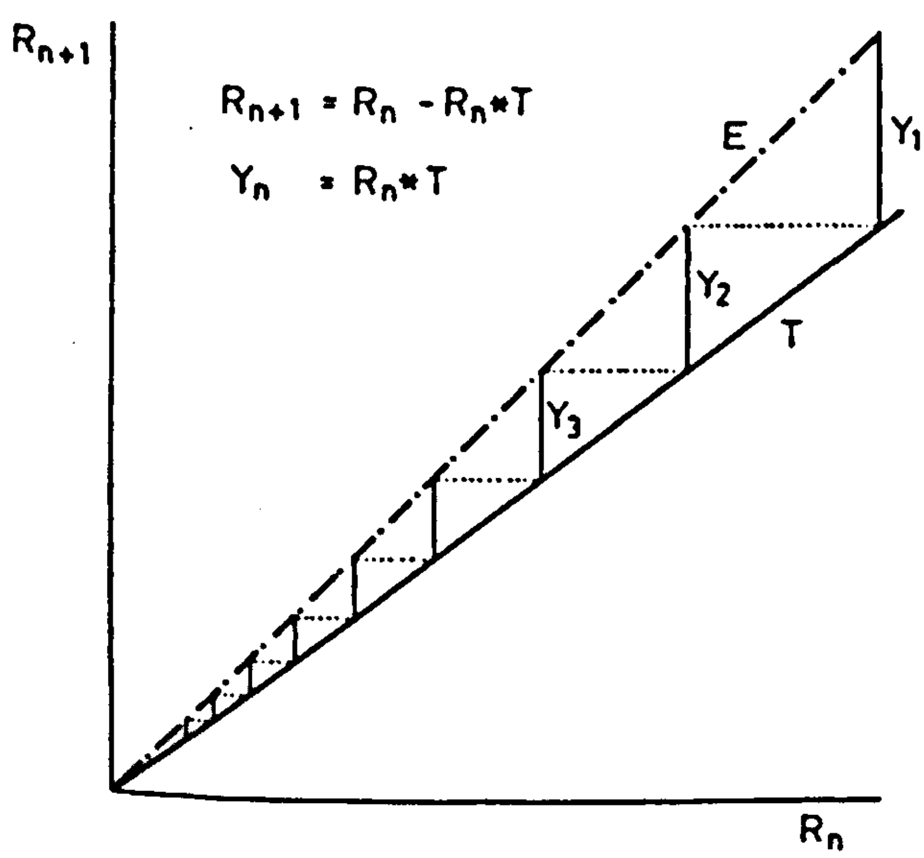

Figure 59. Relation between 'Reichtum' (R_x) in successive years, Tätigkeit (T) and yields (Y_x) in the absence of enrichments.

These equations are graphically presented in Figure 59. The diagonal E represents the points at which R_n equals R_{n+1}. The line T has a slope of $(1 - T_c)$, so that the vertical distance between both lines at any point represents the yield in a given year. Each year, R_n decreases by the fraction $(1 - T_c)$, resulting in a decay to zero in an exponential way.
In practice, however, R_n increases concurrently by weathering, nitrogen fixation, manuring and so on. As a result, R_n and yield will converge towards some non-zero equilibrium value. Fertilizer application serves the purpose of increasing R_n. The activity, T_c, can be manipulated by a variety of cultivation practices, e.g. improving soil aeration, reducing acidity and controlling weeds, pests and diseases.

In the absence of chemical fertilizers, von Wulffen expressed the quantity of manure used in terms of rye equivalents fed to cattle producing the manure and characterized its efficiency by the 'Gattung' (manure coefficient). When the manure obtained by feeding the harvest from a field to man and cattle is returned totally to that field, the manure coefficient equals one, assuming no other additions to the fertility, if the yield of that field neither increases nor decreases. Otherwise, the manure coefficient will be higher than one in some cases (e.g. leguminous crops) and lower when losses occur. The latter is generally the rule. Extended for enrichments, Equation (95) and (96) transform into:

$$Y_n = (R_n + I_r) \cdot T_c \tag{97}$$

$$R_{n+1} = (R_n + I_r) \cdot (1 - T_c) \tag{98}$$

$$I_r = G_a \cdot G_e \tag{99}$$

Here, the newly introduced I_r stands for increase in fertility, G_e for grain equivalents of manure or other sources of fertility such as weathering, and G_a for the manure coefficient. Both yield and R_n now approach equilibrium values greater than zero, as is illustrated in Figure 60. The two lines E′ and T′ are obtained by shifting the original lines E and T in Figure 59 over a distance I_r away from the origin. Now each year the yield is equal to the vertical distance between lines E′ and T′ and the net annual change in R_n to the vertical distance between lines E′ and T′. In the low range this net change is positive; it is negative in the high range. Under otherwise identical conditions, the fertility moves towards the equilibrium point, 'Beharrungspunkt' according to von Wulffen, where yields equal I_r, the annual addition to fertility. Yields could now be controlled by the rate of manuring and by manipulation of T_c and G_a via cultivation practices. In the nineteenth century, many attempts were made to quantify the theory by means of careful book-keeping of yields and manuring. However, the results were disappointing in the long

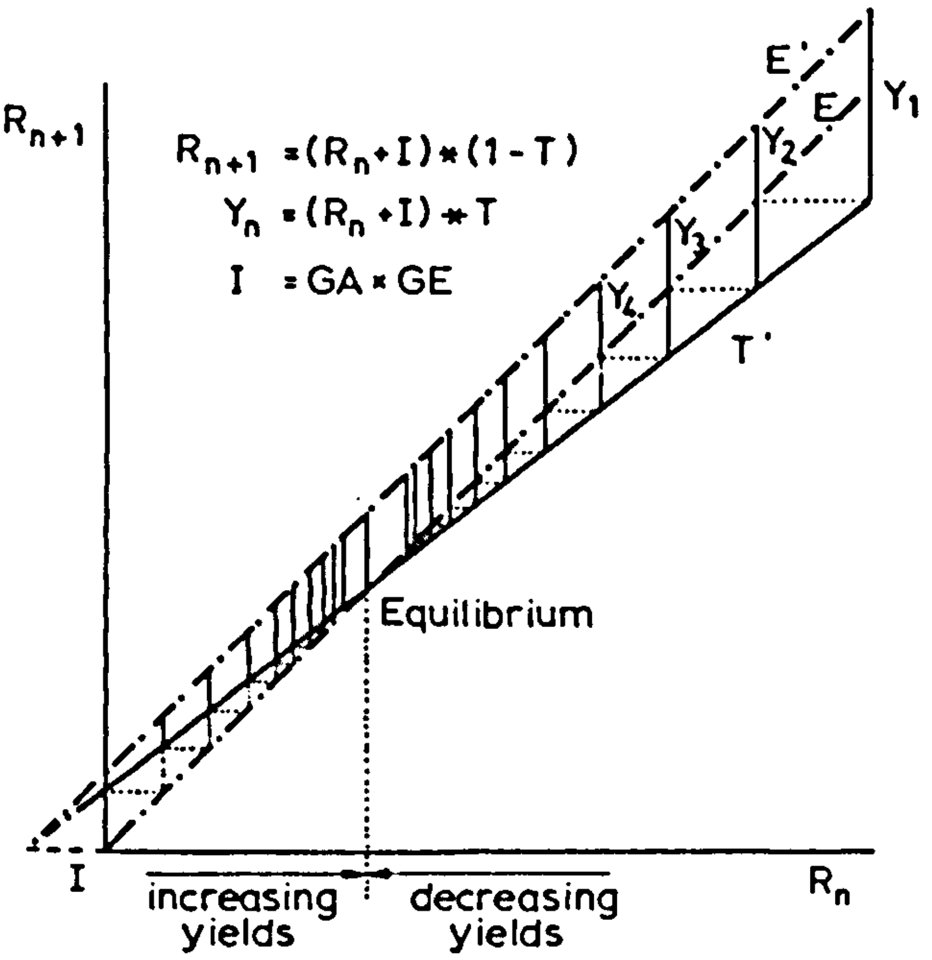

Figure 60. Relation between 'Reichtum' (R_x) in successive years, Tätigkeit (T') and yield (Y_x) with a yearly increase of 'Reichtum' (I).

run, partly because the yields fluctuated too much from year to year, as is illustrated in Figure 58 for rye.

Exercise 83
What is the fertility at the equilibrium point when the activity is 0.09 and the yearly increase in 'Reichtum' amounts to 1200 rye equivalents per hectare?
What will be the annual yield at equilibrium?
What will be the yields in successive years when the activity is increased to 0.16?

6.2.4 Shifting cultivation

Although quantification is difficult, the theory, presented in the preceding subsection, helps to understand agricultural systems. An example in this context concerns shifting cultivation, broadly defined here as any system in which food is produced for a limited period of time from an area of land, after which that area is abandoned temporarily and another piece of land is cultivated (Greenland, 1974). If population density does not impose restrictions on the availability of land, shifting cultivation practices may be succesfully applied to obtain stable food supplies. Under shifting cultivation, the fertility accumulated during many years of rest is depleted by crop yields within a few years. The land is abandoned as soon as yields decline to a level where crop-

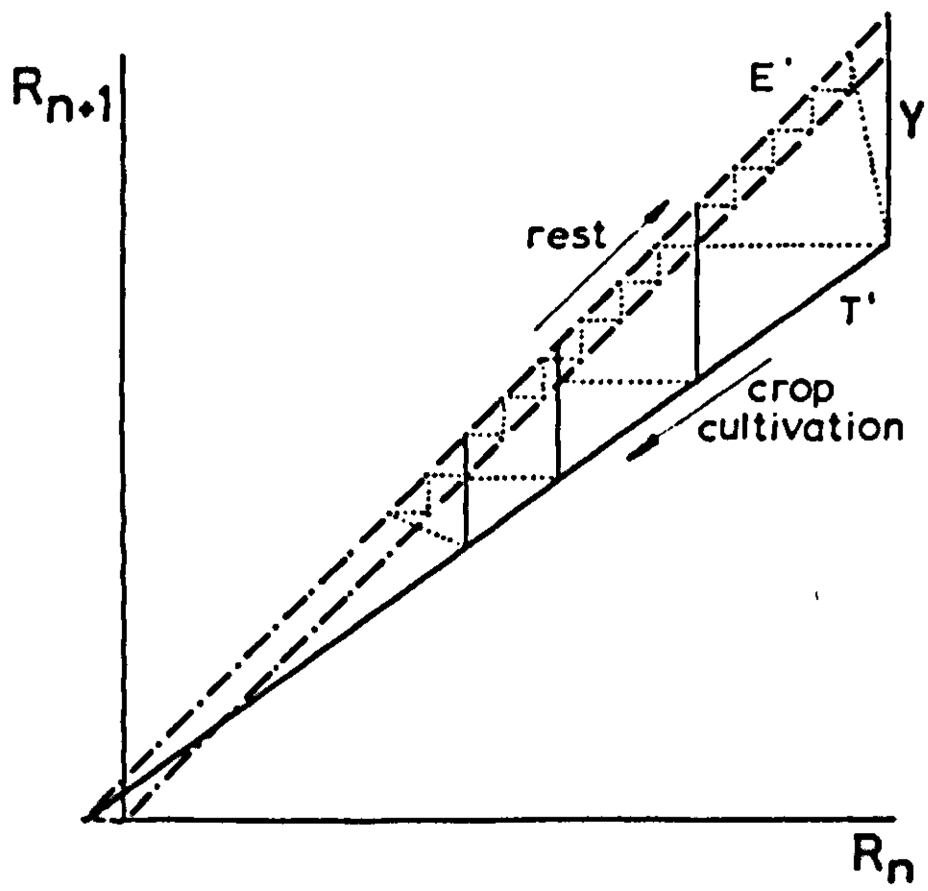

Figure 61. Relation between fertility (R_x) in successive years, activity (T′) and yield (Y) under shifting cultivation presented following von Wulffens theory.

ping is no longer worth the effort. The accumulation of nutrients will then start again by weathering and nitrogen fixation in the semi – natural vegetation.

This course of action is graphically depicted in Figure 61, following the principles outlined in the preceding subsection. There is a small but consistent annual increase in fertility along the line E′ during the years of recovery. After clearing and planting, this accumulated fertility is made available by an assumed activity of 0.1, resulting in its rapid decline along line T. After about four harvests the yield is so low that further cultivation is considered not to be worth the trouble. The land is then abandoned and the cycle starts over again. Figure 62 shows the course of fertility and associated yields with time. In this example, a saw – tooth pattern, with a period of 17 years, is established.

Along these lines it is easy to illustrate what will happen if, for instance, the recovery period, possibly due to increasing need for food, is reduced. The initial fertility at the start of the cropping period will then be lower, resulting in smaller and possibly fewer harvests. Yields may even be too low to justify the effort of any cultivation at all. In principle, it may be possible to overcome an inferior fertility by increasing the activity by better cultivation practices. This assumes, however, that subsistence farmers have not developed good farming systems; in general this assumption is wrong. Moreover, increasing the annual uptake results in a more rapid decrease in fertility, the purpose of which is highly questionable.

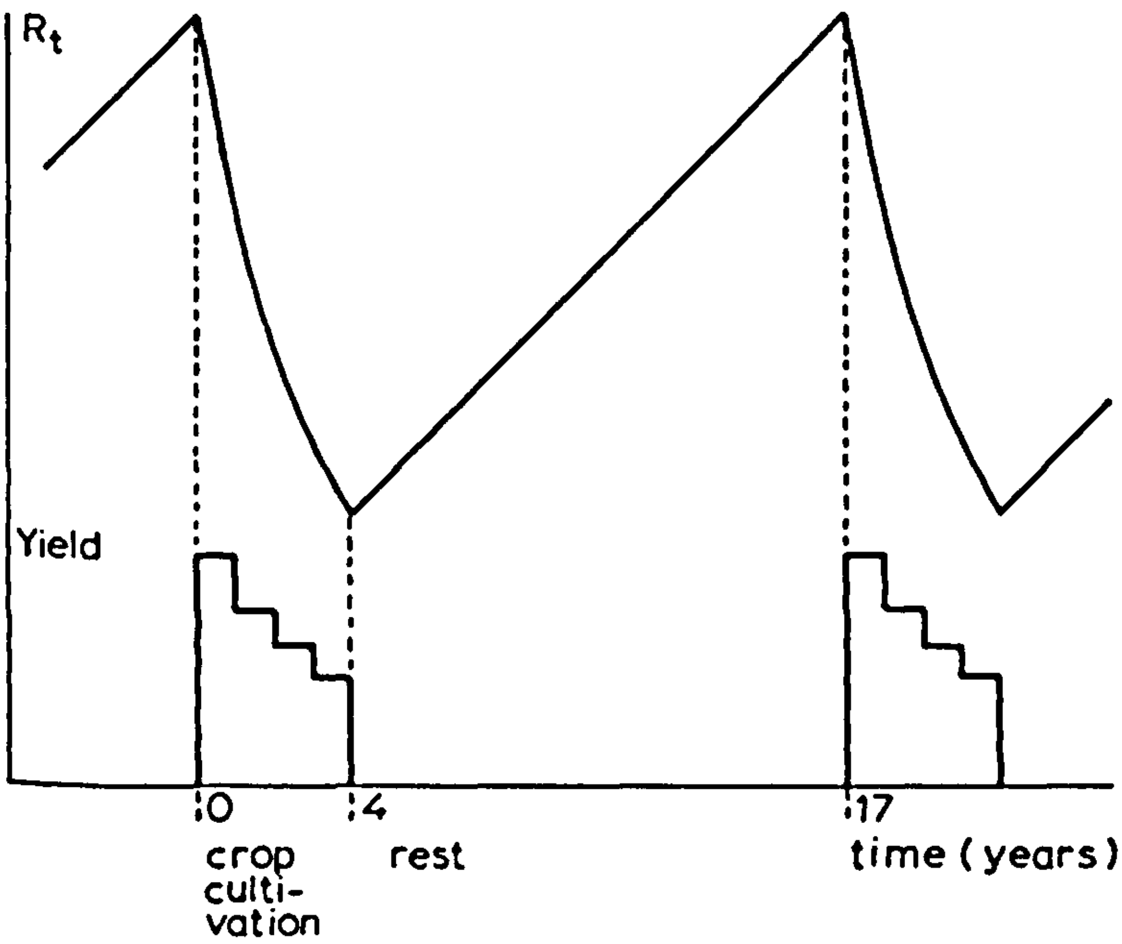

Figure 62. Decline and recovery of fertility and the course of associated crop yields in time under shifting cultivation.

Exercise 84
Calculate the annual levels of fertility and the yield in the case that, due to weathering, the first is increased by 120 kg ha^{-1} each year and for the following situations:

Activity	Fallow period years	Number of harvests
0.08	15	4
0.16	15	4
0.08	10	4
0.16	10	4
0.08	15	3
0.16	15	3
0.08	10	3
0.16	10	3

What are the average yields during the 3 or 4 year cultivation periods; what are they during the whole cycle of 10 or 15 years? In what respect are the 15 years recovery/3 years cultivation schedules superior compared to all others?

Shifting cultivation is a good agricultural system for as long as it lasts. However, with increasing man/land ratio the period of recovery decreases, so that ultimately the yield will decline to a level dictated by the annual inputs of nutrients into the system. These are often so low that they cannot sustain the efforts of farming. Under such conditions other measures should be taken that maintain fertility at a satisfactory level and allow permanent cropping.

One of the possibilities is the exploitation of areas not suitable for arable cropping by keeping animals as part of the agricultural system. From large areas of pasture land the manure can be collected and concentrated on crop land. In the long run, crop yields will be proportional to the amount and quality of manure collected. Because the system is open for nitrogen much more than for the minerals, which remain in circulation, the arable land in such systems tends to become nitrogen deficient. The annual supply of nitrogen to the grassland due to rain and some nitrogen fixation may be about 10 kg ha^{-1}. Even with proper grazing and with proper handling of the manure not more than one – quarter of it is actually available for the arable crop. For example, it may be assumed that 80% of the nitrogen is taken up by the edible portion of the grass, 80% of the grass is grazed off, 20% of the nitrogen is lost by excretion in the field, another 20% during storage in the manure and the recovery in arable crops is 50% or less. Thus at least 4 – 5 hectares of pasture are necessary to collect sufficient manure to increase the nitrogen supply to the arable crop by 10 kg ha^{-1} and to double in this way the grain yield to a level of about 1500 kg ha^{-1} (Section 4.1).

6.2.5 Paddy cultivation in monoculture

In the middle of the nineteenth century the delta of the Irrawady river in lower Burma was almost unpopulated. The few farmers then cultivating the land in this area produced all of the family's food supply, mainly rice, by the efforts of the various members of the family. Birma traded rice with Europe in exchange for textiles and other Western commodities, but the quantities exported were limited. The opening of the Suez Canal in 1859 provided a shorter route to Europe. This made it much more profitable to grow rice for export, so that many more farmers settled here to reclaim the land for paddy cultivation. The land is very suitable for paddy, and because of the uniformly heavy rainfall during a fairly reliable monsoon season, there is little danger of crop failure by lack of water. For six months, rainfall exceeds potential evapotranspiration (Figure 63), so that about three months are available for land – preparation and transplanting, the most labour intensive activities. With bullocks or water buffaloes these activities require about 400 h ha^{-1} (Table 70), depending on the intensity of puddling and levelling. If it is assumed that for a family of six the labour availability is 3 man – days per family per day and that there are 25 eight hour working days per month, 600 working hours per month are available. Such a family could thus cultivate 600/400 or 1.5 ha per month. If, as is the case in lower Burma, the transplanting period may be extended to three months, the family may be able to cultivate 4.5 ha.

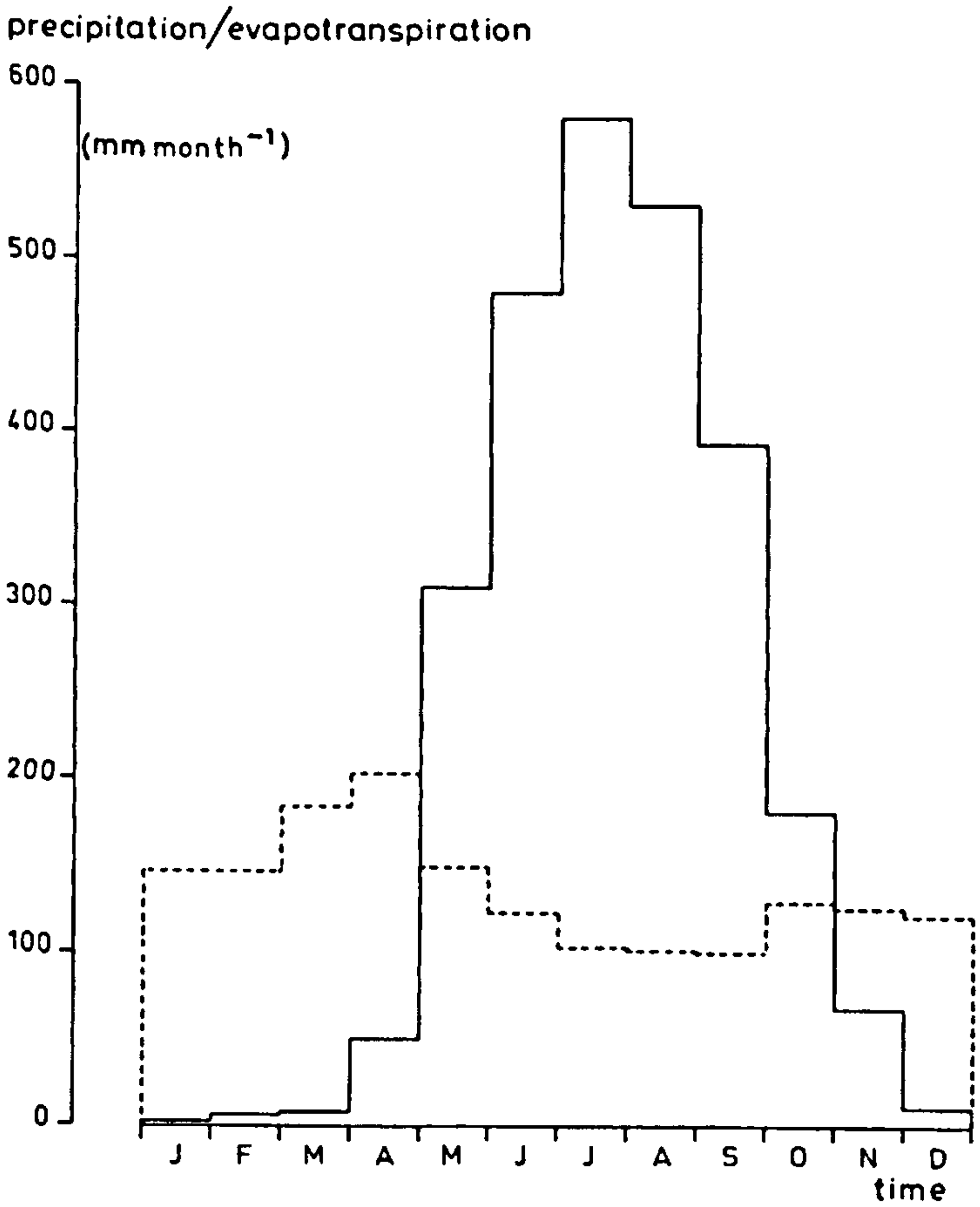

Figure 63. Average monthly precipitation and potential evapotranspiration (dotted line) at Rangoon, Burma.

According to Andrus (1948), this is close to the farm size in lower Burma of a family without hired help. The family of six needs about 2000 kg of paddy per year for consumption (Subsection 6.2.2) and, according to Andrus, it sells about half of the paddy to cover needs other than food. Hence, paddy yields have to be close to 1000 kg ha^{-1}. This appears to be the yield level that may indeed be maintained in many parts of the delta without the use of external inputs (chemical fertilizers). Because in this system a substantial part of the production is marketed, it is not an example of a pure subsistence system. Nevertheless, it illustrates very well how agricultural systems are constrained by labour availability on the one hand, and fertility of the soil on the other.

Further east, the rainy season is shorter and less reliable, resulting in a shorter transplanting period for rice and hence a smaller acreage that can be handled. Northeastern Thailand may be taken as an example. In this region, rainfall exceeds potential evapotranspiration for five months only (Figure 64) and the transplanting period is restricted to one month. This means that the activities related to transplanting, requiring 400 man – hours per hectare, have to be performed in a single month. Assuming a family size of six members, again providing a labour capacity of 600 man – hours per month, at most 1.5 ha of paddy can be grown. Given the subsistence requirement for a six – mem-

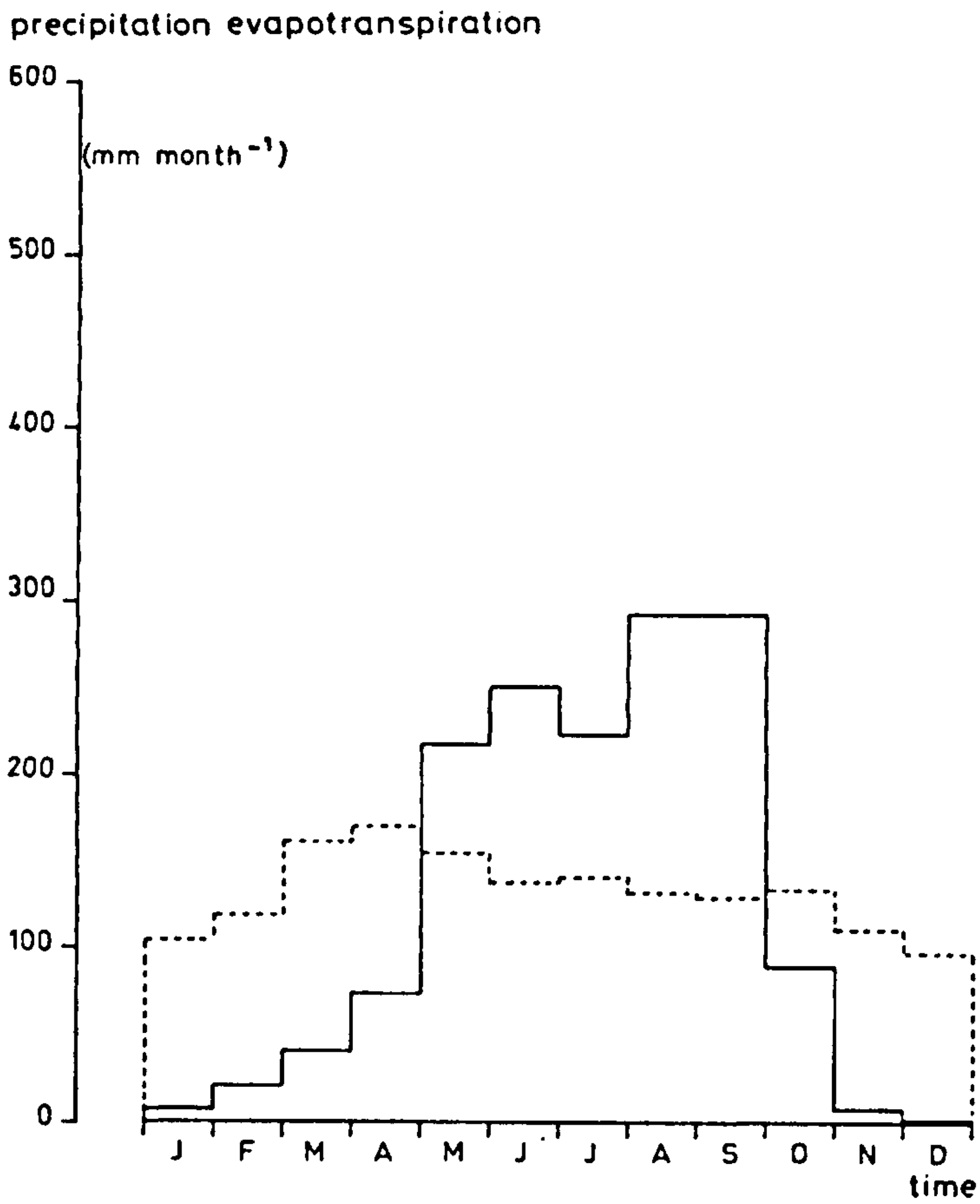

Figure 64. Average monthly precipitation and potential evapotranspiration (dotted line) at Udon Thani, N.E.-Thailand.

ber family of 2500 kg paddy (Subsection 6.2.2), the yield must exceed 1670 kg ha^{-1}. Compared with the actual yields of 1350 kg in northeastern Thailand, this figure is high. It shows that farmers there cannot be self–supporting by paddy cultivation alone under low–input agriculture. On the other hand, much labour remains idle at other times of the year that could be used for other production activities.

6.2.6 A crop mix example for northeastern Thailand

As shown in the preceding subsection, rice monoculture does not provide the subsistence requirements in northeastern Thailand. In that situation the only possibility is the introduction of other production activities with a utilization pattern for the constraining resource that differs from that for rice. Because the only resources used in low–input agriculture are land and labour, the emphasis is placed on making good use of the resource requirements of different crops. The labour demand of a crop in a certain region can be visualized in a labour profile as in Figure 65 for rice in northeastern Thailand. This picture shows that the area under paddy cultivation is predominantly limited by the labour requirements for levelling, puddling and transplanting,

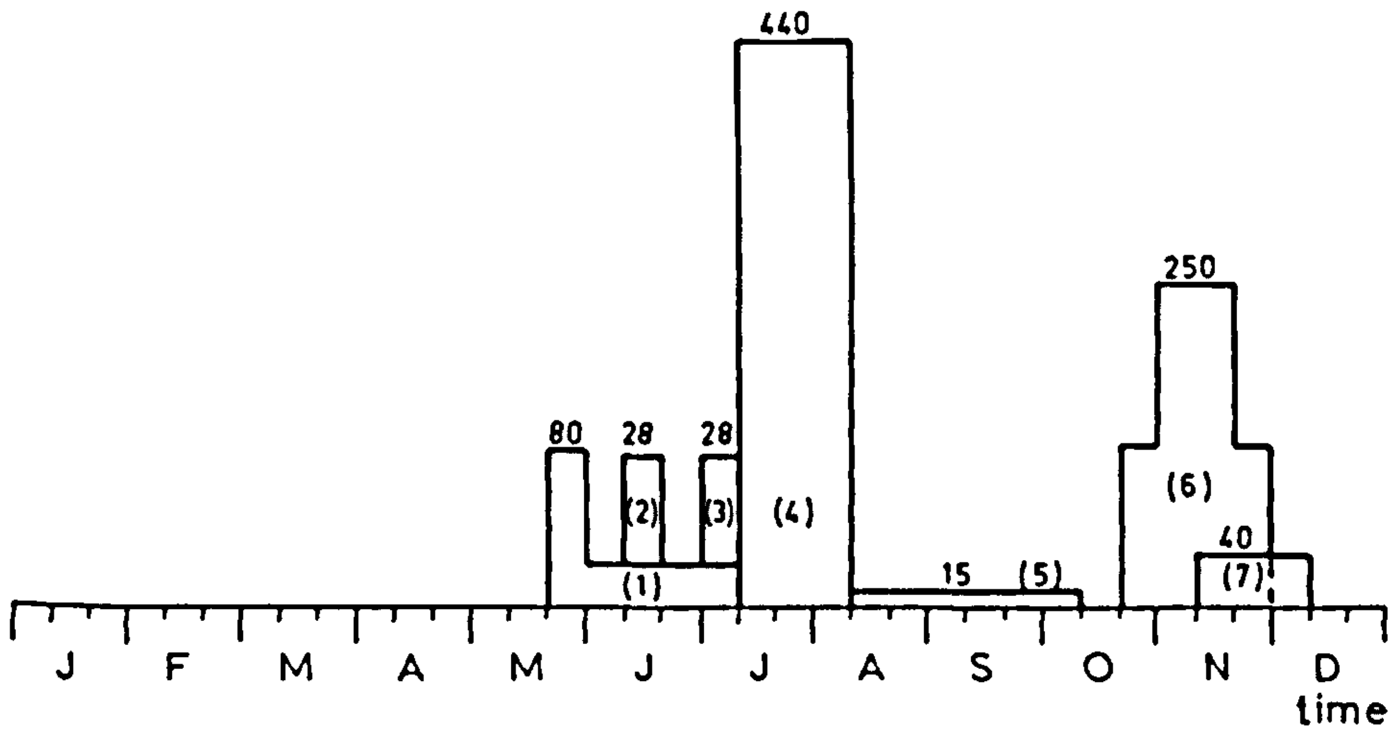

Figure 65. Labour film for paddy cultivation in northeastern Thailand using draught animals; labour requirement in manhours per hectare. (1) seedbed preparation and maintenance. (2) first ploughing. (3) second ploughing. (4) transplanting and related activities. (5) crop maintenance. (6) bird scaring. (7) harvesting.

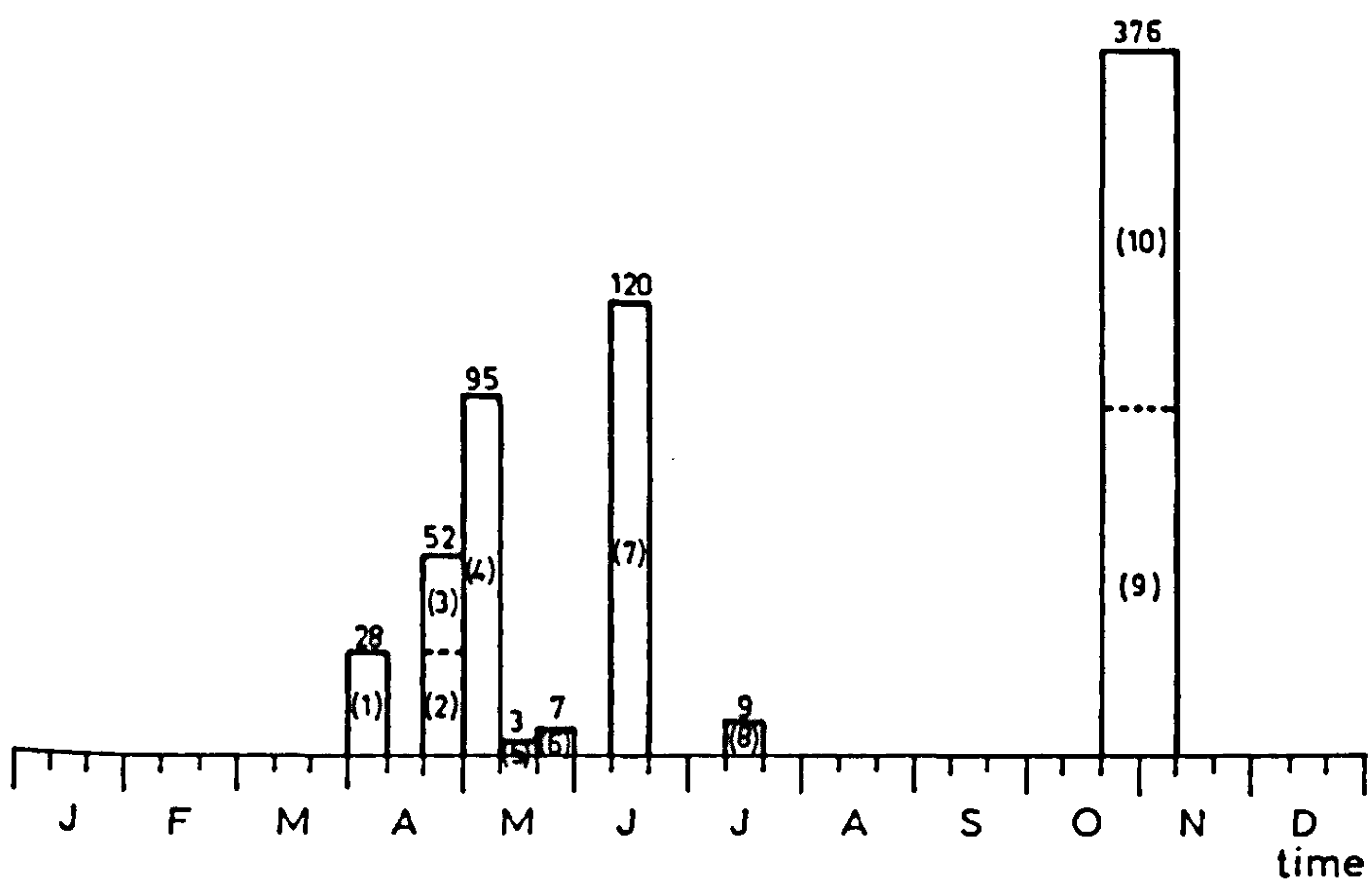

Figure 66. Labour profile for kenaf cultivation in northeastern Thailand using draught animals; labour requirement expressed in manhours per hectare. (1) clearing. (2) first ploughing. (3) second ploughing. (4) harrowing. (5) sowing. (6) fertilizing. (7) cutting (at 1500 kg ha^{-1}). (8) bundling (id.). (9) soaking (id.). (10) handling retted kenaf.

which have to be performed within a single month. Only other crops that do not compete for labour at the same time, can be grown.

Kenaf, a fibre crop, is such a complementary crop, as shown by the labour profile in Figure 66. Comparison of both labour profiles shows that there is practically no concurrent demand on labour at any time. However, kenaf production is severely limited by the heavy labour requirement for retting and associated activities. A yield of 800 kg retted and baled kenaf per hectare

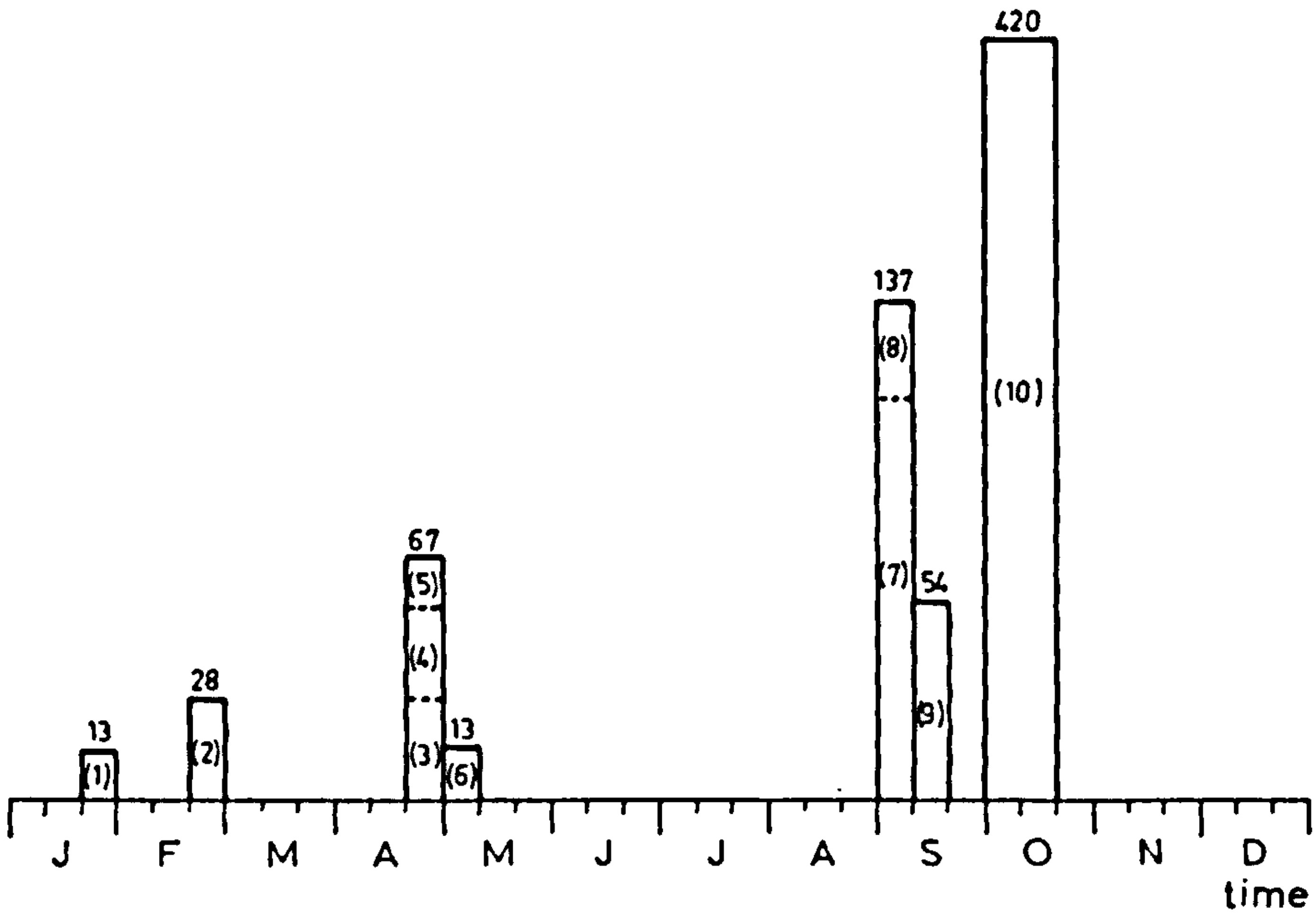

Figure 67. Labour profile for cassava cultivation in northeastern Thailand using draught animals for land preparation, cultivation and hilling-up; all other activities by hand labour; labour requirement expressed in manhours per hectare. (1) first ploughing. (2) second ploughing. (3) harrowing. (4) planting. (5) fertilization. (6) cultivation. (7) weeding. (8) earthing-up. (9) topping, lifting (at 12 t ha^{-1}). (10) transporting.

requires as much as 225 man-hours within twenty days. Because a six-member family is able to produce about 400 man-hours in such a period, at most 1.8 hectare of kenaf can be grown. Since the price of 1 kg kenaf is about equal to the price of 1.5-2.5 kg paddy, an equivalent of about 3000 kg paddy can be grown in this way. This is sufficient to fill the gap between actual and required production.

Still another crop could be introduced to optimize labour use. With respect to labour demand, the next most favourable crop is cassava. Only hilling-up (Figure 67) coincides with the transplanting of paddy, but this requires very little labour. The fairly heavy labour demand for transport at the end of the growth cycle refers to commercial cassava growing, where harvesting is concentrated. If cassava is grown for private consumption, harvesting is spread over a much longer period, thus reducing the labour requirement. A six-member family, living on cassava only, would require about 4700 kg fresh cassava roots annually, a yield that can be obtained from one hectare under most circumstances. From the labour profiles it appears that it is possible for one family to grow 1.3 ha of paddy, 1.1 ha of cassava and 1.8 ha of kenaf. All of the latter is then sold and, depending on price and preference, part of the paddy and the cassava could be marketed, leaving sufficient food for the family to cover subsistence needs.