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Workshop agroecology

Paris : CIHEAM
Options Méditerranéennes : Série Etudes; n. 1984-I

1984
pages 137-145

INPUT-OUTPUT RELATIONSHIPS OF NORTH CHINA COLLECTIVE FARMS

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Key Words: China, Energy, Inputs, Recycling.

ABSTRACT

An energy analysis of 14 advanced North China collective farms was used to examine the production properties of this type of agricultural system. Energy inputs from fossil fuel derived sources (fertilizer, pesticides, machinery) approximately balanced energy outputs of food grain and livestock to state markets. Crop net production was approximately 40×10^6 kcal . ha^{-1} . yr^{-1}, which is comparable to U.S. corn production under good management and is also the level of net primary production expected from predictive equations for natural vegetation based on climate. About 55 % of crop production is used by consumer populations of humans and livestock and about 23 % is directly recycled back to the cropland. Of the energy consumed about 30 % is recycled.

Inputs, outputs and crop production per hectare are not related to size of farm but there is a significant direct relationship between crop production and inputs.

RESUMEN

El análisis de energía de 14 granjas colectivas avanzadas de China Norte se utilizó para examinar las propiedades productoras de este tipo de sistema agrícola. Los inputs de energía provenientes de fuentes derivadas de combustible fósil (fertilizante, pesticidas, maquinaria), equilibran aproximadamente outputs de energía de grano alimenticio y ganado para los mercados estatales. La producción neta de cultivos era aproximadamente de 40×10^6 kcal . ha^{-1} . $año^{-1}$, lo que es comparable a la producción de maíz de los EE. UU. con buen manejo, y constituye, igualmente, el nivel de producción primaria neta a partir de ecuaciones de predicción para la vegetación natural basada en el clima. Alrededor del 55 % de la producción de cultivos es utilizada por las poblaciones consumidoras, humanos y ganado, y aproximadamente un 23 % se recicla directamente de nuevo al cultivo. De la energía consumida, un 30 % es reciclada.

Inputs, outputs y producción de cultivo por hectárea, no están relacionados al tamaño de la granja, pero existe una relación directa muy significativa entre la producción de cultivos y los inputs.

INTRODUCTION

This report utilizes information being prepared for publication (Han *et al.*, 1984) which will discuss the details of energy analysis of 14 collective farms and communes in North China. The purpose of this brief report is to examine data relating to the input and output of energy from 14 collective farms for the present symposium. We will be concerned with the balance between energy input and output, rates of recycling energy in system maintenance, and the effect of size of farm on these energy processes.

The primary study on which the analysis is based was made in 1980 by a team of specialists from Chinese agricultural colleges and universities. The 14 farms represented "advanced" farms which produced an acceptable level of food grains for the state market. Of course, the object of the study was to determine the production factors characteristic of advanced farms so that they could be applied to farms unable to contribute significantly to food grain production.

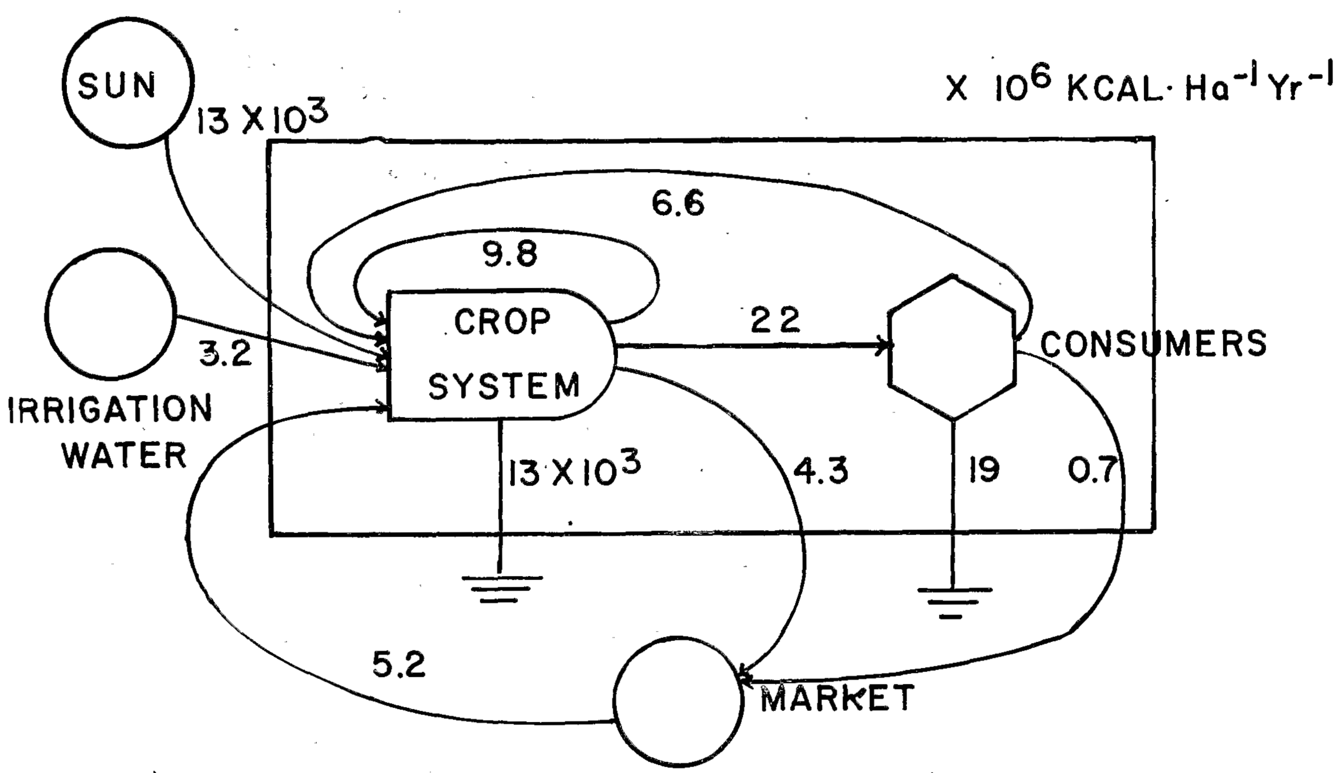
The area of interest is the Huang-Huai-Hai River basin, which is typical in terms of rural population density and cropland productivity for China. The annual precipitation ranges from 500 to 800 mm and the average annual temperature is from 10° to 14° C. The alluvial soil of loess has been cultivated for centuries and has a level of organic matter below 1 percent. Water is a primary limiting factor. About two-thirds of the rainfall occurs in the summer and there is considerable variation between years. In recent years there has been a great effort made to improve and irrigate these farms.

All of the farms were active in production of food grains, which is primarily wheat; cotton was also produced on most farms and several produced oil crops, green manures, fodder and fruit from orchards. Pigs, sheep and goats were also produced on most farms. All farms had draft animals and small birds or poultry and rabbits.

ENERGY DYNAMICS OF AN AVERAGE FARM

We will begin the analysis by taking a conceptual, systems approach to an average farm (based on the average of 14 collective farms) using the symbology of H. T. Odum (1983) (Figure 1). The central element in the model is the crop subsystem which receives its major input from the sun (13×10^9 kcal ha^{-1} . yr^{-1}) which provides the energy for photosynthesis, evaporation, transpiration, heating, and so on. Irrigation water is also an input and its energy value was calculated as the chemical potential energy in rain

Figure 1. Simplified system diagram for energy flow to an average North China collective farm, based on a sample of 14 advanced farms.



(Odum and Odum, 1983, page 26), since the water is mainly used in evapotranspiration. The other input to system is from the human society and is in the form of machinery, fuel from tractors, pumps and machines, pesticides, and fertilizers. The primary output measured in the study was export to the state market. The output of heat from the system is shown as symbols in Figure 3, but was not measured. Heat outputs were estimated by subtraction. The factors used to convert inputs and outputs in this study were taken from the literature and in the case of the man-made materials represent the energy required to manufacture the object. For crops, animals, and humans the energy values represent the energy in the material when measured by calorimetry or expended by metabolic activity.

Internally there are two subsystems (Figure 1). The crop system includes all organic production by plants. The consumer system groups human and animal populations. Consumers are linked to plants via labor and manure. The crop system also has inputs from non-crop systems within the farm, as well as mulch and green manure. The consuming populations receive their energy from the crop system and produce an output to the market. Most of the energy received by the crop producing system and the consuming system is lost as heat.

The behavior of this simplified system is clear. While the overall inputs and outputs of the farm system are balanced, as required by thermodynamics, this merely reflects fitting the heat loss to the inputs by subtraction. What is more to the point, the inputs generated by man from the market almost balances the outputs to the market (5.2 compared to 5.0 $\times$ 10^6 kcal ha^{-1} . yr^{-1}). This means that in energy terms the farms pay for the fossil-fuel derived inputs from the urban section with the outputs to the urban section. The system is neither subsidized nor producing an excess. Actually this apparent balance is a little misleading. First, the inputs do not include costs such as the construction of the irrigation system (the cost of pumping water and maintaining canals is included), agricultural advice, and

Figure 2. Relationships between size of farm fossil-fuel derived inputs and outputs for 14 advanced collective farms in North China.

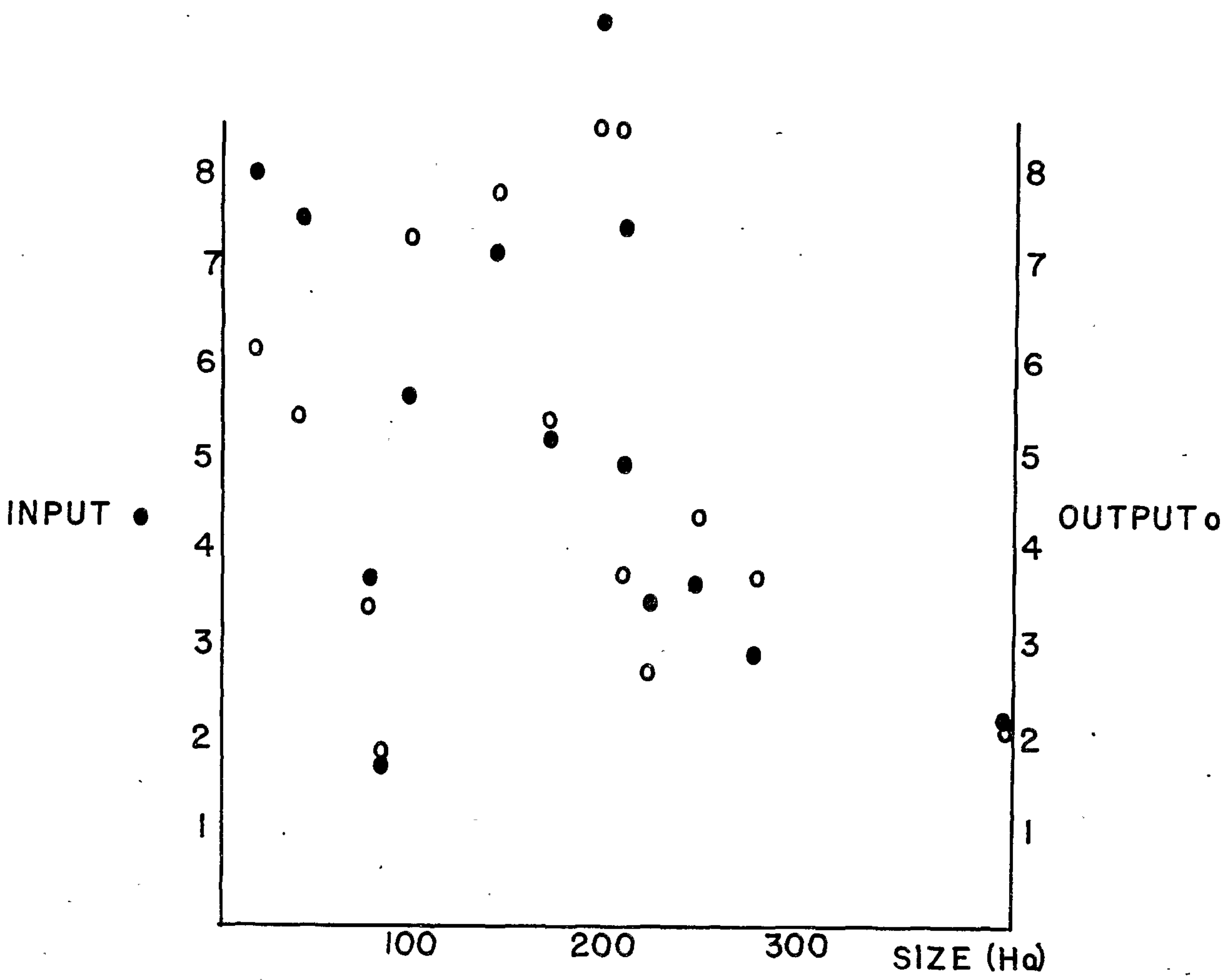


Table 1. Size of farm, population, and system inputs and outputs derived from fossil fuel for 14 North China collective farms in 1980.

Farm Number	Size (ha)	Population	Input 10^3 kcal ha^{-1} yr	Output 10^3 kcal ha^{-1} yr	Out Input
1	20.7	186	8058	6079	0.75
2	40.0	360	7537	5300	0.70
3	80.3	327	3696	3355	0.91
4	87.0	310	1715	1803	1.05
5	121.9	641	5678	7325	1.29
6	169.9	3042	7144	7757	1.09
7	178.7	1328	5203	5333	1.02
8	202.3	1090	9674	8400	0.87
9	217.1	1145	7314	8428	1.15
10	217.7	1078	4918	3750	0.76
11	229.7	1480	3378	2781	0.82
12	251.5	2310	2587	4343	1.21
13	284.5	2539	2871	3721	1.30
14	413.3	2094	2131	2050	0.96
$\bar{x}$	178.2	1281	5205	5035	0.97

input of materials other than farming materials to the farm population. We have no idea how large these inputs might be. Second, costs of transportation and processing that take place off the farm are not included in the model. Nevertheless, given the range in managed fossil-fuel derived inputs (1.7 to 9.6 × 10^6 kcal . ha^{-1} . yr^{-1}) and outputs (1.8 to 8.4 × 10^6 kcal . ha^{-1}. yr^{-1}) for all 14 farms we can conclude that probably these flows are in a dynamic balance.

The overall production of the crop system is about 40 × 10^6 kcal . ha^{-1} . yr^{-1}, of which about 55 % goes to the consumer system. About 23 % is recycled and the remaining 10 % goes to the state market as a contribution to the farm system output. The consumer system, in turn, recycled to the crop system about 30 % of this input and sent about 3 % to the market.

This simple diagram indicates that 1) we are examining a system where the vegetation is operating in a normal way, utilizing a little less than 1 % of the energy input as organic net primary production output, 2) the vegetation system is receiving large regulatory inputs from the consuming system internally and externally, 3) the consuming system is operating with a typical terrestrial operating efficiency of about 30 % and finally, 4) the system has a rather small (about 10 %) organic export. This abstract summary reveals a rather typical terrestrial ecosystem. Let us now examine the patterns in more detail to determine how the individual farm systems fit the general model.

DIFFERENCES BETWEEN FARMS

The 14 collective farms differ from one another in several aspects. First, size of farm ranges from 20 to 400 hectares and cropland per farm ranges from 20 to 300 hectares. The human population per farm ranges from 186 to 3042 persons. Hectares per person ranges from 0.05 to 0.28. The smallest farms are not the most densely populated (Table 1).

There is considerable variation in the absolute size of the fossil-fuel derived inputs and outputs (Table 1). However, the ratios between inputs

Figure 3. Crop production related to farm size on 14 North China collective farms in 1980.

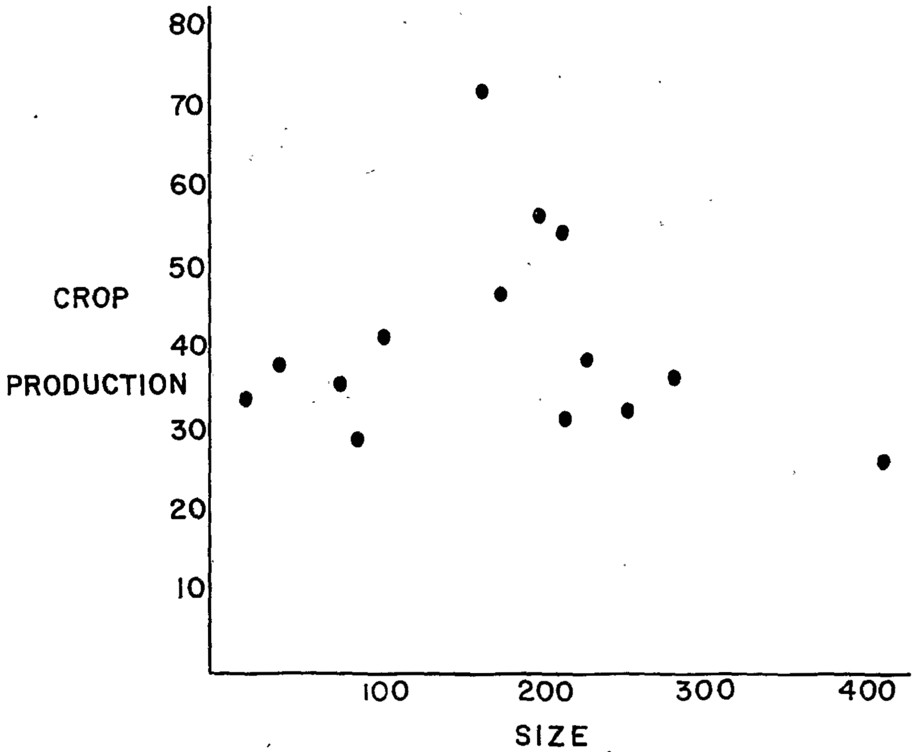


Table 2. Crop production on advanced North China collective farms in 1980.

Farm Number	Size (ha)	Crop Production 10^6 kcal. ha.$^{-1}$ · yr^{-1}
1	20.7	33.9
2	40.0	37.0
3	80.3	35.7
4	87.0	28.7
5	101.9	40.1
6	169.9	71.9
7	178.7	47.1
8	202.3	56.2
9	217.1	54.5
10	217.7	31.0
11	229.7	38.6
12	251.5	32.3
13	284.5	35.8
14	413.3	25.2
$\bar{x}$	178.2	40.6

Figure 4. Relationship between energy recycled to crop production and crop production on 14 North China collective farms in 1980.

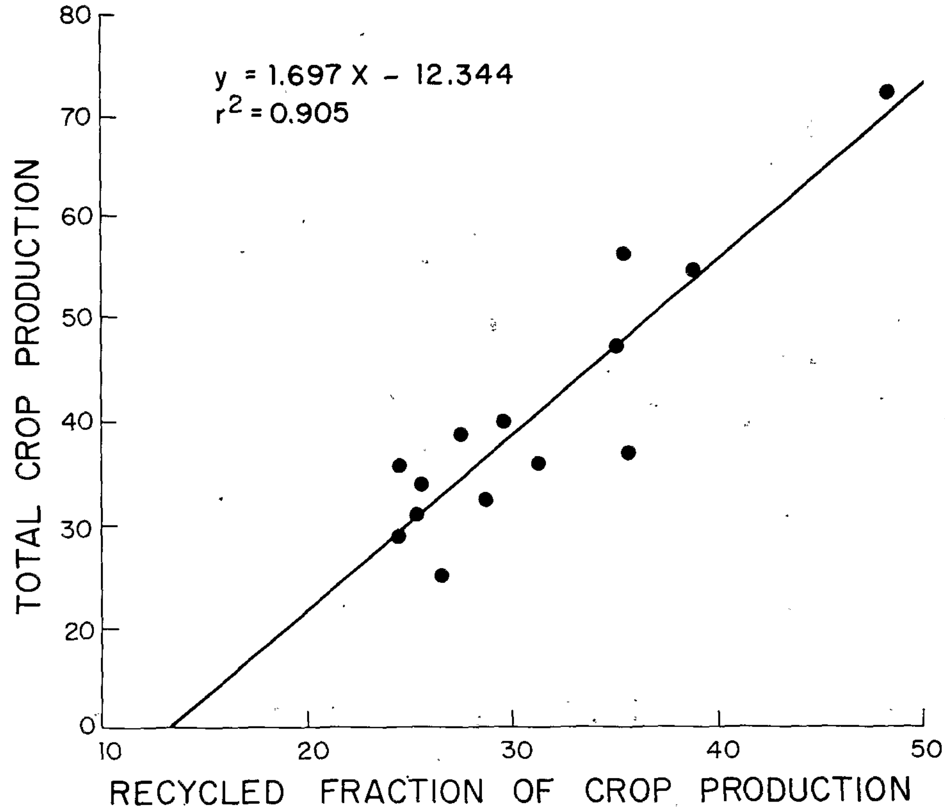


Table 3. Energy recycled to crop production directly through green manure and mulch and through the consumer components on 14 advanced North China collective farms in 1980.

Farm Number	Crop Production 10^6 kcal. ha.$^{-1}$ · yr^{-1}	Recycled to Crops 10^6 kcal. ha.$^{-1}$ · yr^{-1}	Percent Recycled
1	33.9	14.6	43
2	37.0	16.0	43
3	35.7	12.8	36
4	28.7	20.6	72
5	40.1	17.1	43
6	71.9	19.6	27
7	47.1	20.0	42
8	56.2	23.1	41
9	54.5	18.4	34
10	31.0	13.0	42
11	38.6	13.9	36
12	32.3	13.7	42
13	35.8	15.6	44
14	25.2	12.1	48
Average	40.6	16.4	40

and outputs were near unity for most farms. Seven farms produce more output than they receive as input. There is no obvious pattern of size of either input or output with size of farm (Figure 2). Lowest input and output was observed for both a small and a large farm; high input or output occurred on small and medium sized farms.

Crop production also varies among the farms (Table 2) with a range of 25 to 72 × 10^6 kcal . ha^{-1} . yr^{-1}. Crop production also appears to be farm size neutral (Figure 3).

One of the most important features of these agroecosystems is the recycling of materials and energy to the crop production system. Earlier we noted that about 30 % of the energy received by the consumer subsystem is recycled to the crop subsystem. In addition, energy is recycled directly as green manure and mulch and a relatively small (0.7 × 10^6 kcal . ha^{-1} . yr^{-1}) quantity is obtained from non-crop systems on the farm. All of this recycled energy (Table 3) amounts to about 40 % of the crop production. The range in percentage is quite narrow (27 to 48 %) with one exception—a farm in which a large quantity of green manure was recycled. Farms with larger rates of production tend to recycle a larger percentage of energy to crop production (Figure 4).

Finally, there is a clear tendency for crop production to increase with input (Figure 5), although at higher input levels the relationship is less tight. The relationship is described as Y= 3.3X + 23.4, with an R^2 value of 0.63. There appears to be the beginning of a flex point at the highest input levels, suggesting that further increases in crop production may not follow further increases in fossil derived inputs. This pattern is not clear and we can only suggest that a flex point may occur. However, when all inputs to crop production (that is, the fossil derived input and the recycled energy) are considered (Figure 6) then a more significant direct relationship is observed. This relationship is described as Y= 1.84X + 0.9, with an R^2 value of 0.73.

The contrast between these two relationships is interesting. On Figure 5, the two points where there are high inputs but lower crop production represent the two smallest farms. These farms are above average in use of fuel, fertilizer, pesticides, and machinery. Even though we concluded earlier that crop production was size neutral, possibly there are size limits in the ability of the farm to apply fossil-derived inputs to crop production. Such limits are well known for use of farm machinery.

Figure 5. Relationship between input energy from fossil-fuel derived sources to crop production and crop production on 14 advanced North China collective farms in 1980.

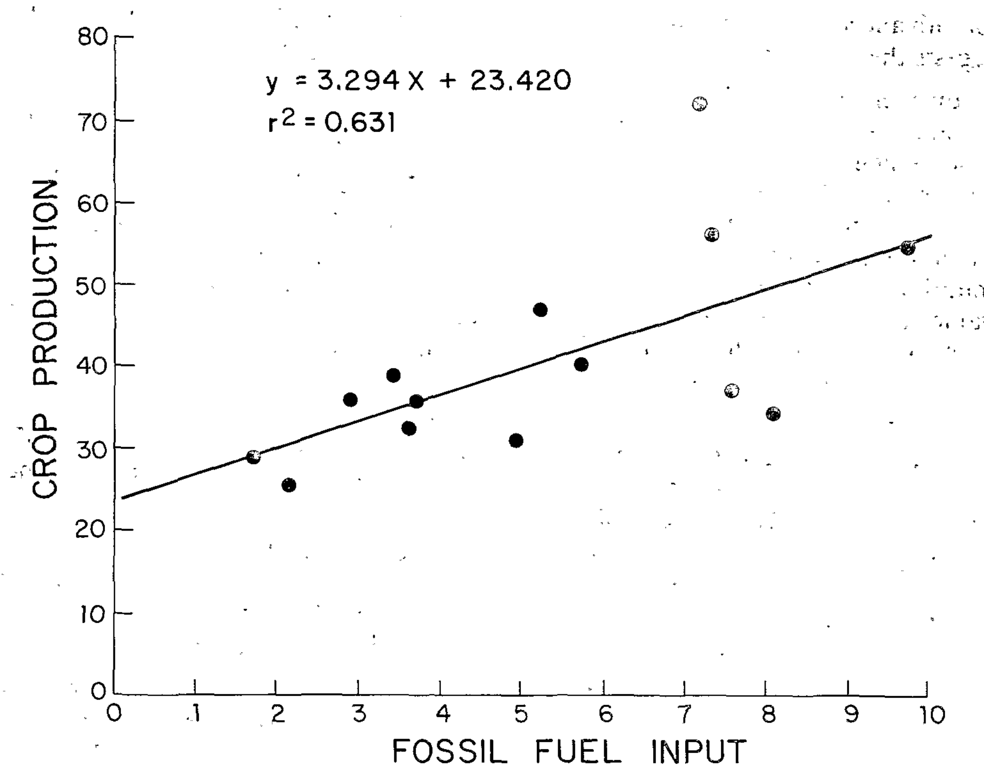
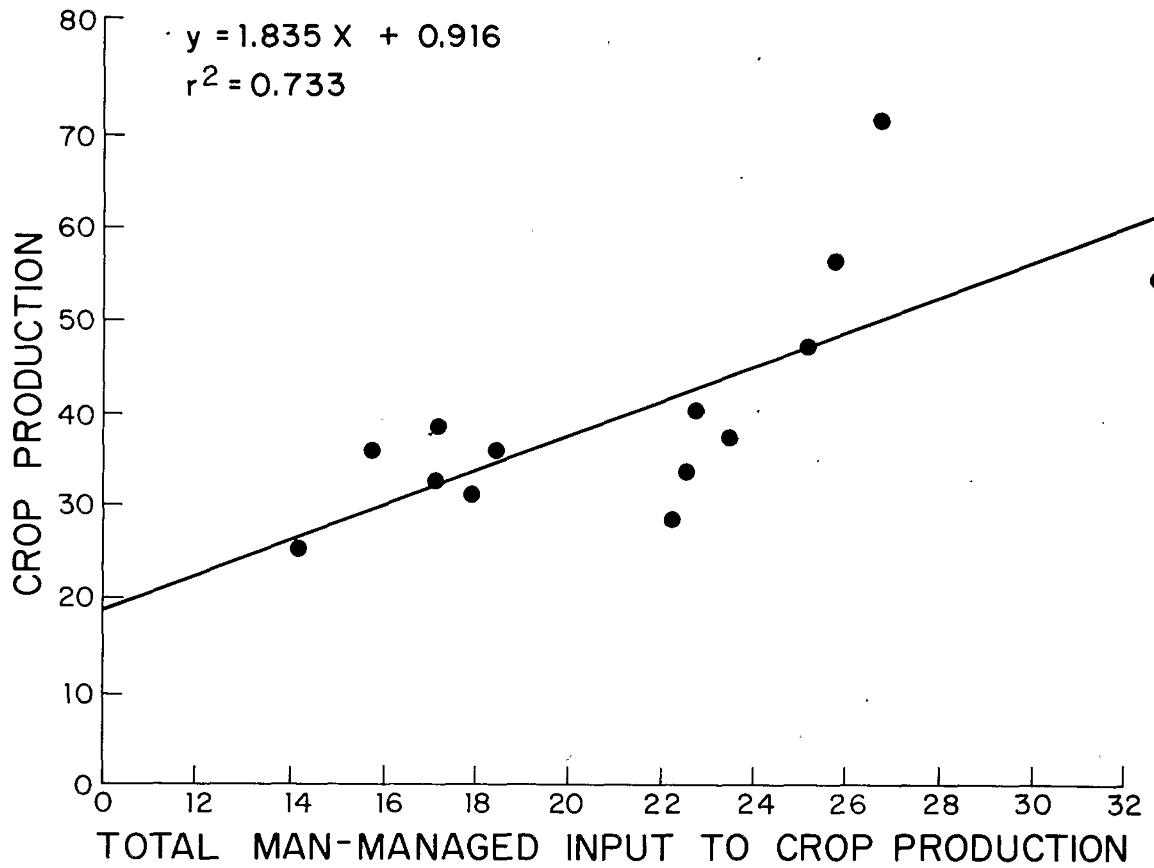


Figure 6. Relationship between all fossil-fuel derived and recycled inputs to crop production and crop production on 14 North China collective farms in 1980.



CONCLUSIONS

This analysis of advanced collective farms in North China suggests the following conclusions:

1. When one considers a farm as an energy system it is possible to compare the various dynamic behaviors which represent exchange of energy, currency, materials, and information. The problem is that energy is not a universal currency and, therefore, the comparison using energy has limitations. It might be useful to adjust energy values to represent different qualities. However, in our opinion the data were inadequate to make such adjustments for these Chinese farms.

2. The energy behavior on the average collective farm appeared to be similar to that for a typical terrestrial ecosystem. The major difference between these agroecosystems and a natural ecosystem was that a relatively larger amount of energy was transferred to the consumer component, as compared with decomposer populations, in the farm systems.

3. The outputs to and inputs from the market are in general balance. On the average these farms are not subsidized by the urban systems but rather provide food which is exchanged for commodities needed on the farm. About 80 % of China's population is rural and about one out of five persons must be supported by export from farms. Input-output ratios may not be useful for comparing agricultural systems if the urban-rural proportions of populations are unequal in the compared systems.

4. The crop production system has a relatively high level of productivity. The average rate (40×10^6 kcal . ha^{-1} . yr^{-1}) can be compared to Pimentel and Wen's (1984) estimate for a U. S. corn crop of 49×10^6 kcal . ha^{-1} . yr^{-1}. It is also approximately equal to that expected for natural vegetation on the basis of Lieth's (1975) predictive equations using temperature and precipitation.

5. Crop production is not related to size of farm; the farms have about the same per hectare production. However, there is a relationship between crop production and its inputs.

6. Considering the relation between crop production and recycled energy from within the system, there is a direct positive relationship,

although the farms with highest production recycled a lower percentage of energy.

7. Considering the relation between crop production and fossil-fuel derived inputs, there is an increase in variation as the level of input increases and there is a suggestion that an inflexion in the curve is occurring at the higher input rates. These patterns are created by the smallest farms which, contrary to the observation that crop production is size neutral, may not be able to efficiently apply fossil-fuel inputs. More data are needed to verify this supposition.

8. However, when fossil-fuel inputs and recycled energy are summed there is a direct positive relationship between crop production and these inputs, with no evidence of a change in the shape of the relationship. These data suggest that adjustment of the recycled inputs rates allow the farms to maintain high production levels.

9. Clearly farm management policies can influence the observed patterns. The 14 farms were selected to represent successful farm systems. Communes, which are larger units containing several collective farms, were also studied by the research team and were found to have a lower crop production rate (21 $\times$ 10^6 kcal . ha^{-1} . yr^{-1}). Thus, the levels of production of the 14 farms represent what can be obtained in this environment, rather than the typical or average pattern. The analysis suggests that production may be most responsive to internal system inputs although this tendency runs counter to the apparent practice since at higher production levels a lower percentage of energy is recycled.

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