Working Paper

RESOURCES, ENVIRONMENT AND TECHNOLOGY OPTIONS FOR FOOD PRODUCTION AND SELF SUFFICIENCY IN KENYA

M. M. Shah
G. Fischer

November 1982
WP-82-127

International Institute for Applied Systems Analysis
A-2361 Laxenburg, Austria

RESOURCES, ENVIRONMENT AND TECHNOLOGY OPTIONS FOR FOOD PRODUCTION AND SELF SUFFICIENCY IN KENYA

M. M. Shah
G. Fischer

November 1982
WP-82-127

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
2361 Laxenburg, Austria

FOREWORD

Understanding the nature and dimension of the food problem and the policies available to alleviate it has been the focal point of the Food and Agriculture Program at the International Institute for Applied Systems Analysis (IIASA) since the program began in 1977.

In the program we are not only concerned with policies over a five to fifteen year time horizon, but also with a long term perspective to obtain a comprehensive understanding of the food problems of the world.

As we anticipate over the coming decades a technological transformation of agriculture which will be constrained by resource limitations and which could have serious environmental consequences, a number of important questions arise.

(a) What is the stable, sustainable production potential of the world? of regions? of nations?

(b) Can mankind be fed adequately by this stable, sustainable production potential?

(c) What alternative transition paths are available to reach desirable levels of this production potential?

(d) What are sustainable, efficient combinations of techniques of food production?

(e) What are the resource requirements of such techniques?

(f) What are the policy implications at national, regional and global levels of sustainability?

Stability and sustainability are both desirable properties from the considerations of inter-generational equity as well as of political stability and peace.

We hold environmental considerations to be of critical importance in answering the questions posed.

This report presents the preliminary results of a case study of Kenya carried out as a part of the FAO/Kenyan Government/IIASA Collaborative Project.

As understanding of the ecological and technological limits of food production is a critical part of agricultural development planning, this report highlights the results for Kenya and the methodology of evaluating agricultural production potential, population supporting capacity and soil degradation hazards. Policy relevance and implications for Kenya are briefly discussed.

Kirit S. Parikh
Program Leader
Food and Agriculture Program

ACKNOWLEDGEMENTS

We have benefitted from the insights and assistance of many people within Kenya, FAO and IIASA. In particular we acknowledge the contribution of the following.

Within Kenya

J. Lijoodi, Head, Development and Planning Division, Ministry of Agriculture

Y. Masakhalia, Permanent Secretary, Ministry of Planning

F. Muchima, Head, Kenya Soil Survey

L. Ngugi, Head, Human Resources Division, Ministry of Planning

N. Nyandat, Director, National Agricultural Laboratories

Within FAO

R. Dudal, Director, Land and Water Division

G. Higgins, Project Coordinator, Land and Water Division

J. Hrabowsky, Senior Policy and Planning Coordinator, Agricultural Department

A. Kassam, Consultant, Land and Water Division

Within IIASA

C. Csaki, Food and Agriculture Program

K. Parikh, Food and Agriculture Program

F. Rabar, Food and Agriculture Program

Special thanks are due to Cynthia Enzlberger for typing this manuscript.

CONTENTS

RESOURCES, ENVIRONMENT AND TECHNOLOGY OPTIONS FOR FOOD PRODUCTION AND SELF SUFFICIENCY IN KENYA

M. M. Shah and G. Fischer

1. Introduction

The extent to which natural resources, namely land, climate and water, can produce food and agricultural products is limited. The ecological limits of production are set by soil and climatic conditions as well as by the specific inputs and management applied. Any "mining" of land beyond these limits will, in the long term, only result in degradation and ever-decreasing productivity unless due attention is paid to the preservation, conservation, and enhancement of the natural resource base.

Recent demographic estimates suggest that Kenya's population growth rate of 3.9% is one of the highest in the world. The future domestic requirements for food, industrial raw materials and export crops require sound policies of agricultural land use, especially if sustainability of production is to be ensured in the long term. What is the stable and sustainable production potential in Kenya? What are the levels of population that can be adequately supported by this potential? What trade patterns may be necessary to ensure sufficient food? What are the technological requirements and how can the alternative transition paths be achieved? These central issues of agricultural development planning in Kenya are being investigated within the FAO/IIASA–Kenya collaborative Agroecological Zone Project entitled "Land Resources for Populations of the Future – A Case Study of Kenya" (FAO, 1979). The work in Kenya consists of three phases, as described in the following.

- Phase 1: Analysis carried out on the basis of a 10,000 ha land unit as inventoried from the FAO–UNESCO Soil Map for Kenya. This phase was completed at the end of 1979.
- Phase 2: The basic land unit of 100 ha is inventoried on the basis of a 1:1 million Kenya Soil Map (Kenya, 1980). Detailed country information is used to develop a two-season rainfall inventory, to identify present crop-specific technology and input use, to assess soil erosion, productivity losses and conservation requirements, and to develop methodology for determining crop choice and technology requirements. This methodology, for example, considers aspects of food self-sufficiency and quantifies the input and technology requirements.

- Phase 3: The feasibility and policy implications of alternative technology paths, cropping patterns and environmental conservation are being investigated in conjunction with the IIASA Food and Agriculture Model of Kenya.

Phases 2 and 3 are presently in progress. In this paper the discussion is limited to a description of the overall methodology and preliminary Phase 1.

2. FAO agroecological zone (AEZ) methodology

The methodology and computer programs (Fischer and Shah, 1980) for the assessment of agricultural production potential are based on methodology (FAO, 1976, 1979) fundamental to any sound evaluation of land. The methodology developed is used to assess land suitability and potential yield for each of the 18 food crops (including livestock) considered in the study (Fig. 1). (FAO, 1979 a, b.)

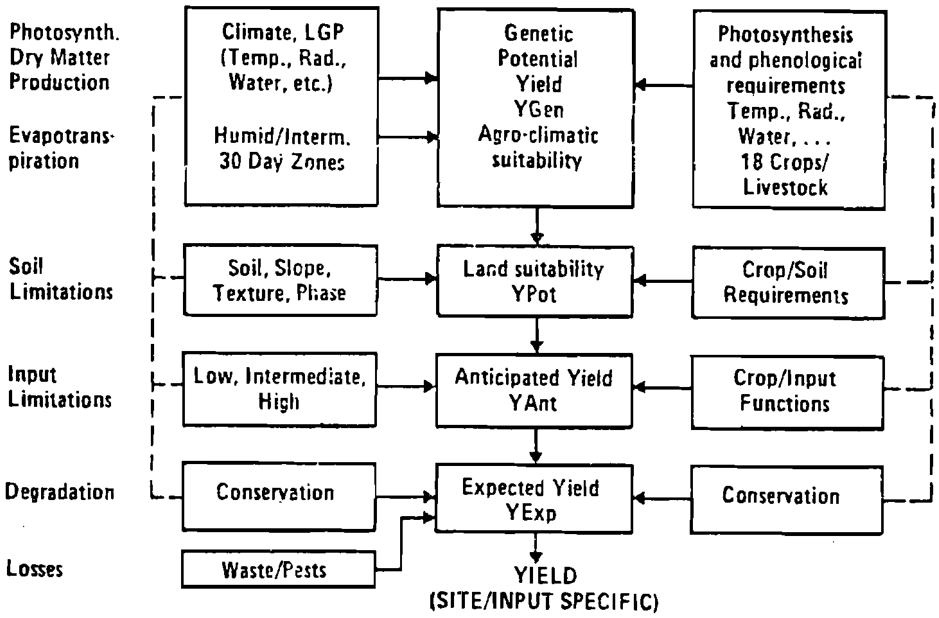

Figure 1. FAO Methodology and Crop Yield Model.

Fundamental to the assessment is the soil,climatic and land use inventory.

In phase 1 this inventory comprised overlay of a specially compiled climatic inventory on to the 1:5 million FAO/UNESCO Soil Map (FAO/UNESCO, 1971–79). The climatic inventory differentiated four major climates and thirty-two length of growing period (LGP) zones at 30 day intervals (e.g. 120–150 days). Measurements of the unique agroecological zones resulting from this combination allow quantification of the land resources in terms of soil and climatic conditions.

In Phase 2 the computerized Kenya Agroecological inventory comprises overlay of

-- 1:1 million soil map of Kenya (Kenya Soil Survey, 1982)

-- Present and projected irrigation areas and production

-- Present and projected forest areas

-- Present and projected cash crop areas and production
-- Present and projected population by location
-- Present crop mix by location
-- Climate inventory comprising of eight climate types
-- Length of growing period inventory distinguishing six classes of growing periods per year
-- National ground reserves by location

The first step in the methodology is to match the climate and LGP inventory with the specific crop requirements to assess the agroclimatic suitability in terms of genetic potential yield. The main features of the climatic inventory created by FAO for the assessment of agroclimatic crop suitability (Kassam, 1979) are as follows.

(a) Classification of crops into climatic adaptability groups according to their fairly distinct photosynthesis characteristics.

(b) Classification of temperature and moisture requirements of crops. The quantification of heat attributes and moisture conditions is based on the actual temperature regime during the growing period and a water balance model comparing precipitation with potential evapotranspiration.

Individual crop productivity rules (Kassam, 1979), as determined for each major climate and length of growing period zone, permit the assessment of agro-climatic crop yield. This is modified by next considering the soil limitations. The resultant potential yield (land suitability) is adjusted according to the input level. Table 1 shows attributes of each of the three input circumstances used in the assessment. Note that the assumption of only three discrete input levels is for simplicity and convenience. The Phase 2 study considers an alternative mix of technology and crops for specific districts in Kenya.

Table 1. Attributes of Input Levels.

ATTRIBUTE	LOW INPUT LEVEL	INTERMEDIATE INPUT LEVEL	HIGH INPUT LEVEL
Market Orientation	Subsistence	Subsistence/ Commercial	Commercial
Capital Intensity	Low	Intermediate	High
Labor Intensity	High	High	Low
Power Sources	Hand Tools	Improved Implements and/or Animal Traction	Complete Mechanization
Technology Employed	Local Cultivars No Fertilizer No Pest Control No Disease Control	Improved Cultivars "Sub-Optimum" Fertilizer Some Chemical Pest and Disease Control	High Yielding Cultivars "Optimum" Fertilizer Chemical Pest and Disease Control
Land Holdings	Small, Fragmented	Small, Fragmented/ Consolidated	Large Consolidated

The input limitations allow the quantification of the anticipated yield. The final step in the methodology is to take account of environmental conditions in terms of productivity and waste losses. The climate, length of growing period, soil characteristics (soil, slope, texture, and phase) and input levels determine the environmental conditions in relation to a particular crop. Degradation of land takes place in many ways, water erosion and wind erosion being the most obvious in rain-fed agricultural production. The productivity loss caused by the rate of soil loss under various climatic, soil, and land use circumstances has been quantified in the form of a degradation model (FAO/UNEP/UNESCO, 1981).

The yield and potential production for each of the 18 crops are assessed for the land actually available for rain-fed production. The available land is derived by making appropriate allowances for nonagricultural land requirement, irrigation land requirement, cash crop land requirement, national game parks, forest land requirement and rest period (fallow) land requirement.

The application of the methodology (Fig. 1) to each unit of available land will result in a number of crops (less than 18) that can be potentially produced. A decision regarding the crop choice for each unit of land depends on the objective function, namely:

(a) maximize calories subject to a protein constraint;

(b) maximize calories subject to the present Kenya crop mix constraint;

(c) maximize net revenue subject to year 2000 production targets (domestic demand and exports targets for basic food commodities)

(d) as in (c) but with additional resource constraints.

For a specific land unit, crop and input level environmental conservation will be required to ensure sustainability of production. The degradation model consists of a soil erosion model and a productivity loss model (Shah, et al 1982)

3. Results

In this paper typical results are discussed. Complete detailed results are given elsewhere (Shah and Fischer, 1981, Fischer and Shah, 1982)

4. Assessment of arable land and crop production potential

The aim here is to evaluate the maximum production for each crop of the assessment under the assumption of a particular level of inputs and conservation measures. An example of the results for maize, (wheat, sorghum and millet) is given in Table 2.

The results suggest that if conservation measures are implemented, then the potential arable land for low, intermediate and high input levels in the year 2000 will be about 8.31, 6.92 and 5.77 million ha respectively. However, the percentages of "good" arable land (excluding low productivity land) are 71%, 73% and 81% respectively for the three input levels. The area of arable land presently (1975) under cultivation is about 3.9 million ha. The potential loss due to soil erosion for maize varies from 29% (high technology) to 50.7% (low technology). Also note the large potential for sorghum and millet in comparison to wheat.

Table 2. Available Land Resources in Kenya and Potential for Production/Soil Erosion Productivity Losses for Maize, Wheat Sorghum and Millet—Year 2000.

	Low Technology*	Intermediate Technology*	High Technology*
Rainfed Arable Land† ('000 ha)	8313	6923	5771
% VH + H	27.2	31.4	27.7
% M	44.1	42.0	53.7
% L	28.7	26.6	18.6
Potential for Rainfed Production† ('000m.t)			
With Soil Conservation			
Maize	1280	4732	9964
Wheat	836	2315	3511
Sorghum	938	3716	7403
Millet	662	2719	6062
Without Soil Conservation			
(% Loss in Production Potential)			
Maize	50.7	37.9	29.0
Wheat	41.7	31.4	24.3
Sorghum	48.5	38.9	29.5
Millet	43.7	37.4	29.3

VH = Very High, H = High, M = Moderate, L = Low, respectively refer to suitability.
* Low Technology assume Low Inputs, No Soil Conservation and continuation of present crop mix. Intermediate Technology refers to intermediate inputs, 50% Soil Conservation and a mixture of present crop-mix and "optimal" crop-mix. High Technology refers to High Inputs, Full Soil Conservation and "optimal" crop mix. Here the "optimal" crop-mix is crop-mix yielding maximum calories with a minimum of protein.

5. Assessment of population-supporting capacity

The calorie and protein production values for each of these alternative assessments are translated into a population-supporting capacity. Here the Kenyan requirement is assumed to be 2380 calories and 38.8 grams of protein per capita per day. The results for the population-supporting capacity and inputs (fertilizer and power) required are given in Table 3.

Table 3. Year 2000 Population Supporting Capacity of Kenya.

	Low Input PCMIX*	Intermediate Input 0.5 PCMIX/0.5 OPTMIX†	High Input OPTMIX
Projected Population (mill.)	31.5	31.5	31.5
With Conservation			
Potential population (mill.)	8.8	23.4	51.4
Fertilizer '000 mt	9	317	811
Power (mill. MDE)§	248	404	668
Without Conservation			
Potential population (mill.)	6.4	16.4	38.4
Fertilizer '000 mt	7	294	807
Power (mill. MDE)	213	375	633

* PCMIX = Present Crop Mix continuing to year 2000

† OPTMIX = Maximize calorie with protein constraint

§ MDE = Man Day Equivalent

The results suggest that the projected year 2000 population cannot be supported under the assumption of low and intermediate input levels. At least a mixture of intermediate and high input technology will be required if Kenya is to meet its food needs. A comparison of the with and without conservation potentials also highlights the importance of soil conservation.

6. Assessment of meeting Year 2000 production targets

In this case the basic issue considered is:

"Given the year 2000 production targets, domestic demand and exports for basic food commodities in Kenya, what is the extent and location of land resources that can fulfill these targets? What will be the consequence of resource constraints? What will be the impact of soil erosion on productivity and production?"

We assume that farmers operate on the basis of profit maximization. The LP model is formulated to facilitate a "best" choice of technologies (low, intermediate or high), and crop mix (out of the 18 food crops under consideration) for each unit of land on the basis of profitability subject to ecological conditions.

Four alternative scenarios are considered, namely:

Scenario A: No resource constraints and full soil conservation i.e. no soil erosion and no productivity losses

Scenario B: No resource constraints and a 50% level of soil conservation

Scenario C: Resource constraints (Quantity of fertilizers, Nitrogen, Potassium and Phosphorus and power availability in the year 2000 are specified) and full soil conservation.

Scenario D: Resource constraints as in Scenario C and a 50% level of soil conservation.

Data on the production targets, producer prices and resource constraints are given in Table 4. The results for the year 2000 are derived at constant 1975 prices for both the outputs and inputs. A summary of some relevant results for the four scenarios is given in Table 5. For all commodities except maize, banana-plantain, and sugar, the production targets are met in all the four scenarios.

In Scenario A (no resource constraints and full soil conservation) the only commodity for which the production target cannot be met is banana and plantain. In this case 55% of the target can be fulfilled. The total land area required is 4.314 million hectares and out of this 96% would be under high technology. The fertilizer and power required is 536000 mt and 477 million man day equivalent (MDE) respectively. In 1975 the total fertilizer (Fischer and Shah, 1982) and power used for the production of food commodities was about 74000 mt and 319 million MDE. Hence fertilizer usage in Kenya will need to increase at a rate of 7.9% annual up to the year 2000. For power the corresponding rate is 1.6% annually. Kenya's rural labor force is expected to grow at about 3% annually during this period.

In Scenario B the effect of only a 50% level of soil erosion conservation is that the production targets for maize, banana and plantain and sugarcane cannot be met. The shortfall is 3.6%, 65.9% and 27.6% respectively. Furthermore the resources required are also higher than those in Scenario A. The land use, fertilizer and power requirement is 7.4%, 17.9% 10.1% respectively higher than the Scenario A case. In Scenario C and Scenario D, the fertilizer and power availability in the year 2000 are constrained to 370,000 mt and 820 million MDE. Here again the production targets for maize, banana and plantain and sugar cannot be met. For all other commodities the targets are met. For maize the shortfall is 24.6% and 45.9% for Scenario C and D respectively, for banana and plantain the corresponding percentage shortfall is 41% and 47.2% and for sugar 17.7% and 21.6% respectively.

The land use in Scenario C is comparable to Scenario A. A comparison of these two scenarios suggests that the effect of fertilizer and power constraints

Table 4. Year 2000 Production Targets, Resource Constraints and Prices.

Crop	Production Target '000 mt	1975 Production Prices KShs/mt
Millet	409	629
Sorghum	700	629
Maize	5353	693
Phaselous Beans	570	1357
Sweet Potato	1173	240
Cassava	1341	351
Wheat	838	1086
White Potato	537	477
Barley	144	1640
Groundnut	47	1465
Banana/Plantain	290	564
Sugarcane	5020	90
Oilpalm	10	4683
Resource Constraints		
Fertilizer ('000 mt)		
Nitrogen	195	1812
Phosphorous	150	2117
Potassium	27	2093
Power (mill. MDE)	820	4089

Table 5. Resource Use and Net Revenue from Food Production: Kenya Year 2000.

	Scenario A No Resource Constraint Full Soil Conservation	Scenario B No Resource Constraint 50% Soil Conservation	Scenario C Resource Constraints Full Soil Conservation	Scenario D Resource Constraints 50% Soil Conservation
Total Land Use '000 ha	5630	5981	5974	5763
-Crop Land '000 ha	4314	4635	4318	4305
-Full Land '000 ha	1316	1346	1656	1458
% Crop Land: High Input	96.0	98.6	81.8	88.9
Int. Input	3.7	1.3	14.2	7.6
Low Input	0.3	0.1	4.0	3.5
Total Fertilizer '000 mt	536	632	372	369
Total Power '000 mt	477	525	430	417
Net Revenue mill. 1975 KShs	5717	4872	5281	4433
Per Capita Income of Agr. Population	359	306	332	279
Per Hectare Income*	1015	815	884	769

* From production of basic food commodities

would cause a shortfall in production targets for maize and sugar of about 25% and 18% respectively.

In addition to the above differences in the results of the four scenarios, there is another major aspect to be considered. The central feature of the methodology and the LP model is the regional allocation of crops according to ecological suitability and profitability. What implications does this have on the incomes--per capita and per land unit--in each LGP. Table 6 gives a summary of these results by major climate and length of growing period for the four scenarios.

Table 6. Total Net Revenue, Income per Capita and Income per Hectare by Major Climate and Length of Growing Period Zone—Kenya Year 2000.

	Scenario A No Resource Constraint Full Soil Conservation			Scenario B No Resource Constraint 50% Soil Conservation			Scenario C Resource Constraints Full Soil Conservation			Scenario D Resource Constraints 50% Soil Conservation		
	1*	2†	3§	1*	2†	3§	1*	2†	3§	1*	2†	3§
Warm Tropics: Length of growing period (days)												
240-270	162	176	1248	210	228	1707	126	137	969	108	117	831
210-239	317	178	1910	346	194	2084	332	187	1865	289	162	1624
180-209	422	387	1848	313	287	1223	411	377	1605	374	343	1461
150-179	359	292	1408	313	255	1227	253	206	808	287	233	1125
120-149	678	631	1132	524	487	875	592	551	992	457	425	768
90-119	582	283	507	484	235	345	571	278	447	418	203	373
75-89	595	486	385	489	399	317	592	483	383	489	399	317
Sub-total	3116	332	760	2677	286	615	2877	307	669	2421	258	594
Moderately Cool Tropics Length of growing period (days)												
330-365	3	71	3000	2	48	400	3	71	600	2	48	400
300-329	43	211	2389	25	122	928	29	142	1074	23	113	920
270-299	153	291	2068	101	192	1347	152	289	2027	87	165	1160
240-269	131	279	1845	92	196	1227	131	279	1747	86	183	1147
210-239	202	430	1683	151	321	1218	200	425	1639	156	332	1279
180-209	607	816	1238	479	644	976	575	773	1093	492	661	932
150-179	136	156	1236	96	110	793	130	149	1048	96	110	800
120-149	225	273	1355	102	124	534	190	231	995	130	158	681
Sub-total	1500	361	1426	1048	252	944	1409	339	1229	1021	258	938
Cool Tropics Length of growing period (days)												
330-365	1	53	1000	1	53	333	2	106	667	1	53	333
300-329	13	107	1625	11	90	1000	14	115	1077	11	90	1000
270-299	24	80	923	22	74	846	27	91	771	22	74	628
240-269	47	168	1382	36	129	1029	38	136	1086	45	161	1286
210-239	64	235	1143	64	235	1123	104	382	1825	57	209	1055
180-209	602	1406	2724	756	1766	3203	498	1163	2101	599	1399	2415
150-179	231	468	4529	155	314	2768	199	404	3553	110	223	1774
120-149	120	256	1481	102	217	1085	113	241	1202	96	205	1021
Sub-total	1101	463	2303	1147	482	2206	994	418	1875	941	395	1733
National	5717	359	1015	4872	306	815	5281	332	884	4433	279	769

* Net Revenue million KShs 1975 (1 US dollar = 10 KShs)

† Income per capita in KShs

§ Income per hectare in KShs

In scenario A (no resource constraints and full conservation) the per capita income and the income per hectare from food crop production of the agricultural population in Kenya in the year 2000 will be 359 KShs and 1015 KShs respectively at 1975 prices (one 1975 U.S. dollar equals 10 Kenyan Shillings) In 1975 the per capita income of the agricultural population amounted to 496 KShs. Also in 1975 the per hectare income from food production was 1110 KShs and from cash crop production 4280 KShs.

In all the four scenarios the income in the moderately cool and cool tropics climate is higher than that in the warm tropical climate. Also as expected the income in the drier zones is much less than in the wetter zones; e.g. in Scenario A, the per hectare income in the warm tropical climate in the 210-239 day zones is 1910 KShs compared to 385 KShs in the 75-89 days.

For the zone 330-365 days in the moderately cool climate, the per hectare income in Scenario A is 3000 KShs compared to 400 KShs in Scenario B. This shows the seriousness of degradation in specific locations.

The above set of results are preliminary in that they have been obtained on the basis of Phase 1 inventory of Kenya. The refined Kenya case study on the basis of 100 ha units by district and length of growing period/climate will generate a wealth of information that will be useful for planning and policy formulation in Kenya.

7. Policy relevance

The data and information generated in this study are useful for many aspects of agricultural development planning. The policy use (Kenya, 1979) and implications of the study are numerous.

8. Soil erosion and conservation policy

The study generates data on the location of areas where soil erosion may be critical. For a particular area, the analysis provides information on what crops and input levels would reduce the level of soil erosion and resultant productivity losses. The identification of the area susceptible to soil erosion and the conservation measures necessary can be linked to government policy on incentives, public works and employment for conservation.

9. Income distribution policy

One of the major issues facing developing countries is that of income growth and distribution in the agricultural sector. The study has the potential to map out the levels of income on a regionalized (e.g. district, length of growing period etc.) basis. Such information could provide the basis for policies on income distribution, employment generation and non-agricultural development in "poor" areas.

10. Land distribution policy

In the study we have assumed that the year 2000 population distribution over zones will be the same as in the year 1975. In reality the population will migrate due to various social and economic factors. The results of the study in the context of per capita and per hectare income (linked to size of land holdings and population) can be useful for the formulation of policies on land distribution and size of land holdings. This in turn will affect the in and out migration from specific areas.

11. Migration and food distribution policies

The study identifies areas of potential production as well as areas which are or will be critical (the resource base cannot support the resident population). Expected levels of income from food production in terms of per capita and per hectare are also mapped out. Policies on outmigration and/or alternative development are relevant here.

In contrast to outmigration, when the land base cannot produce the local food requirement and sufficient income, is the creation of alternative employment opportunities and the transfer of food from surplus areas. The latter aspect will necessitate investments in transportation, additional food storage capacity and infrastructure development.

12. Domestic food demand and trade policies

Relative prices, shifts in traditions, the marketing system and development have largely been the causes of changes in the domestic food demand (Shah, 1979). For example,the demand for sorghum and millet has declined while the demand for wheat has increased. Does Kenya have the natural resources (climate, rainfall, and land) to satisfy the increasing domestic demand for particular food crops? The results on potential production of individual crops can be incorporated in domestic food policies to "push" (increase demand) for crops with high production potential and to "pull" (decrease demand) for crops with low production potential.

In the past export trade has been concerned basically with nonfood crops. The potential production of some cereal crops, roots and livestock products suggests trade possibilities. The methodology permits an evaluation of this type of issue.

13. National game parks policy

In Kenya there are some 30 national game parks and 21 proposed national reserves. This land area amounts to 11.7% of the total land area. Many of these parks and reserves are situated in marginal areas; however, some areas have considerable agricultural potential. At 1978 producer prices, the value of potential food production from national parks and proposed national game reserves has been estimated (Shah, 1980) to be 83.7 million and 20.1 million Kenya Pounds, respectively. (1 Kenya Pound = US Dollars 2.8)

Kenya is committed at present to preserving its wildlife heritage – the heritage of mankind– but will its population in the next century be forced to reassess this commitment?

14. Concluding remarks and further work

The assessments of food production, environmental impact, technological requirements and population-supporting capacity and incomes from food production have been discussed in this paper. The results of this study together with the IIASA Food and Agriculture model of Kenya will provide a powerful tool for agricultural planning in Kenya.

References

FAO (1976) A Framework for Land Evaluation. Soil Bulletin No. 32. Rome: FAO.

FAO (1979a) Agriculture: Toward 2000. Proceedings of the 20th Session of the FAO, 10–29 November, 1979. C79-24. Rome: FAO.

FAO (1979b) Report on the Second FAO/UNFPA Expert Consultation on Land Resources for Populations of the Future. Rome: FAO.

FAO/UNEP/UNESCO (1981) A Provisional Methodology for Soil Degradation Assessment. Rome: FAO.

FAO/UNESCO (1971–79) Soil Map of the World, Vols. 1–10. Paris: UNESCO.

Fischer, G., and M.M. Shah (1980) Assessment of Population-Supporting Capacities – Overall Computer Programs. WP-80-40. Presented at the FAO/UNFPA Expert Consultation on Methodology for Assessment of Population-Supporting Capacities, in Rome, 4–6 December, 1979. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Kassam, A.M. (1979) Multiple Cropping and Rain-Fed Crop Productivity in Africa. Consultant's working paper No. 5, FAO/UNFPA Project INT 75/P13 AGLS. Rome: FAO.

Kenya (1979) Development Plan 1979–83. Nairobi: Government of Kenya.

Kenya (1980) A 1:1 Million Soil Map of Kenya. Kabete, Kenya: Kenya Soil Survey.

Shah, M.M. (1979) Food Demand Projections Incorporating Urbanization and Income Distribution – Kenya 1975–2000. Nairobi, Kenya: Food and Marketing Project, Ministry of Agriculture.

Shah, M.M. (1980) Assessment of Potential Agriculture Production – Kenya's Wildlife Areas. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Shah, M.M., and G. Fischer (1981) Assessment of Food Production Potential – Resources, Technology and Environment – A Case Study of Kenya. WP-81-42. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Shah M.M., G. Fischer, G. Higgins and A.H. Kassam. (1982) Soil Erosion and Productivity Losses in Agriculture--Methodology and Estimates for the Developing World. FAO/IIASA, forthcoming.

Fischer G. and M.M. Shah. (1982) Food Production Potential and Incomes in Kenya. IIASA, Austria (forthcoming)

Fischer G. and M.M. Shah (1982) Supply Response of Kenyan Farmers--Yield Model IIASA, Austria.

Kenya Soil Survey: 1:1 million soil map of Kenya, Nairobi, 1982.