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Long-Term Consequences of Technological Development: Italian Case Study

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LONG-TERM CONSEQUENCES OF TECHNOLOGICAL DEVELOPMENT: ITALIAN CASE STUDY

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FOREWORD

The Food and Agriculture Program at IIASA focuses its research activities on understanding the nature and dimension of the world's food situation and problems, on exploring possible alternative policies which could improve the present situation in the short and long term, and on investigating the consequences of such policies at various levels -- global, national and regional -- and in various time horizons.

One part of the research activities focussed on investigations of alternative paths of technology transformation in agriculture with respect to resource limitations and environmental consequences in the long term. The general approach and methodology developed for this investigation is being applied in several case studies on the regional level. The reason for the studies is not only to validate the general methodology but also to develop an applicable tool for detailed investigations for a particular region which could then be applied on a number of similar regions.

Furthermore, some specific aspects are being addressed in all these case studies which has been initiated within the IIASA's Food and Agriculture Program. This will allow the behaviour of various systems to be compared, according to the selected aspects, and analyzed (in different social, economic and natural resource conditions) according to the selected aspects. One of the case studies is being carried out for the Mugelo region (Italy). This paper describes the first phase of the study, the problem, the formulation of goals, and the basic methodological framework.

Kirit S. Parikh
Program Leader
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LONG-TERM CONSEQUENCES OF TECHNOLOGICAL DEVELOPMENT - ITALIAN CASE STUDY -

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INTRODUCTION

The main purpose of the introduction is to outline the reasons for selecting the Mugello region in Tuscany for a regional case study in conjunction with the activities of FAP's Task 2. The structure of Italian society and economy has changed substantially since 1960. We try to roughly summarize this trend in Tables 1-3, picking out those elements that reveal the type of changes that have occured.

In Table 1 we summarize the main elements of the Italian economy in 1979, the deficit of trade in agriculture being of great relevance. We must stress that in terms of currency the agricultural deficit is 8000 billion Lire, i.e. between half and a third of the oil payment deficit. If we bear in mind that at least 10% of total oil imports is used in agricultural production, the figures indicating agricultural deficit are even higher. On the other hand, Table 2 shows the changes in society over the past twenty years; 50% of the rural population employed in agriculture turned to other activities especially in the service sector. So migration from rural to urban areas occured. So migration from rural to urban areas occured.

Since 1971 the number of people employed in the service sector has risen from 38.4% to 48% of the total number of employed. Around this time the oil crisis occured, and the Italian economy suffered a decrease in productivity at the same time as the international economy was going through a period of hardship. The increase in the number of people employed in the service sector did not bring about an improvement in the quality of living due to the low efficiency of the sector, economic difficulties, and the drastic change from a prevalent rural culture to an urban and industrial culture. All these reasons together, as well as others not mentioned here, have led to many social and political problems, for example terrorism; terrorism arises in a situation of diffuse discomfort. In Table 3 we try to summarize, from a personal point of view, the

Table 1. An overview of the Italian economy - 1979 - %

	GNP	Employed	Import	Export
Agriculture	8	14	13	3
Industry	42	37	87	97
Services	50	48	-	-

Table 2. Employment trends.

	1961	%	1971	%	1979	%	1971 / % 1961	1979 / % 1971
Agriculture	5.619	28.9	3.243	17.2	2.919	14.0	57	90
Industry	7.919	40.7	8.350	44.4	7.520	37.0	105	90
Services	5.920	30.4	7.238	38.4	9.763	48.0	122	134

Table 3. Social welfare indices

		Quantitative Index				Qualitative Index		
		Education	Housing	Health	Employment	Community cohesion	Conflicts	Attachment to values
North	Urban areas	**	**	**	***	**	***	***
	Rural areas	**	*	**	*	*	**	*
Central	Urban areas	**	***	**	**	***	**	**
	Rural areas	**	*	*	*	**	*	*
South	Urban areas	***	***	***	***	**	**	**
	Rural areas	***	**	***	**	*	*	*

* = unproblematic

** = some problems

*** = serious problems

quantitative and qualitative indices related to this situation, by type of area (urban and rural) in order to stress the differences in psychological attitude between the urban and rural communities. Over the last ten years it has become increasingly difficult to find a house, get a job, the standard of schooling and the health services has also dropped, and worker/manager conflicts have increased. The general adherence to ethical values which enables people to participate in a well-balanced, progressive society have deteriorated. This feature is markedly different in urban and rural areas, in big and small industries, and in the north and the south. So these differences must also be taken into account when making decisions for the future.

The migration of people to the cities and the changes in agricultural structure have given rise to very serious environmental problems, related mainly to water management, in the short and the long run. An uncontrolled water flow has led to erosion, river floods, land slides, and so in the long run it results in a decrease in fertility and therefore precludes farming. In addition, some hill and mountain areas are abandoned which has given rise to serious environmental consequences. This complicated situation necessitates public intervention.

When considering the problems to be faced in the eighties, equal attention must be paid to activities which mainly need renewable resources such as agriculture, and those that mostly require non-renewable resources such as industry.

- Will we be able to continue with the same growth rate of consumption in the future?
- Will the world population continue to increase at the present rate and bring more overcrowding to urban areas?
- Will the values which led to the generation of the first industrial age still be valid in the future?

These questions cannot be answered in a simple way. But we can outline some methodologies which will help us to deal with possible changes in the future.

Based on a short overview of the main features of Italian society and economy we can draw the following conclusions:

- from an economic point of view we need a more efficient agriculture;
- from a sociological point of view we need a balanced population densities between urban and rural areas;
- from an environmental point of view the whole land area of Italy should be under agriculture, and environmental deterioration should be prevented as far as possible.

At this point we should outline the main features of Italian agriculture and the environment in order to be able to evaluate the kind of models required.

The main elements of agriculture, farm structure, labor availability and production types should be reviewed. As far as farm structure is concerned, the number of very small farms is too great (86% of farms with a surface area of up to 10 ha. cover only 35.5% of the total area given to farms - see Table 4) and machinery and labor efficiency is too low. With regard to labor the percentage of people employed in agriculture would appear to be 14% (see Table 1), but if we look at the age classes employed (Table 5) then we can see that 50% of those employed in agriculture are older than 50 years whereas only 9% are between 14-29 years. In the near future we can expect a drastic decrease in the number of those employed in agriculture due to the retirement of those over the age of 50. In Table 6 we have grouped the most important commodities and have compared the rate of production with the export and import rates. It can be seen

Table 4. Farm structure according to size (1970)

	Owner operated		Owner management		Other		Total No.%	
Without land	0.4	-	1.0	-			0.5	-
Up to 1.00	18.4	2.3	14.4	0.4	4.5	0.3	17.6	1.7
1.01 - 2.00	23.4	6.5	17.9	1.2	8.0	1.5	22.4	4.9
2.01 - 3.00	14.0	6.3	11.1	1.2	10.7	3.1	13.7	4.9
3.01 - 5.00	16.2	11.2	12.4	1.9	19.3	8.5	16.1	8.7
5.01 - 10.00	15.3	18.5	13.8	4.0	29.3	23.0	15.7	15.1
10.01 - 20.00	7.5	17.5	10.2	5.8	19.5	28.1	8.1	15.0
20.01 - 30.00	2.1	8.6	4.8	4.6	4.7	11.0	2.4	7.7
30.01 - 50.00	1.5	9.1	4.6	6.8	2.5	8.5	1.7	8.5
50.01 - 100.00	0.8	9.5	4.3	11.4	1.0	6.1	1.1	9.8
above 100.00	0.4	10.5	5.5	62.7	0.5	9.9	0.7	23.7
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 5. Number of people employed by age classes (1979)

Age Classes	Agriculture		Industry		Services		
	No. (miL)	%	No. (miL)	%	No. (miL)	%	
14	9	22,6	17	41,3	15	36,1	42
15 - 19	123	11,9	521	50,3	391	37,8	1.035
20 - 24	169	9,2	854	46,3	822	44,5	1.845
25 - 29	186	7,5	1.041	41,9	1.257	50,6	2.485
Total 14 - 29	488	9,0	2.433	45,0	2.485	48,0	5.406
30 - 34	219	8,3	1.056	39,8	1.378	51,9	2.653
35 - 39	288	11,1	1.012	38,9	1.302	50,0	2.601
40 - 44	372	14,9	941	37,7	1.181	47,3	2.494
45 - 49	432	18,3	859	36,5	1.064	45,2	2.355
50 - 54	482	22,0	732	33,4	975	44,5	2.189
55 - 59	346	24,7	425	30,3	632	45,0	1.403
60 - 64	209	36,9	111	19,7	245	43,4	565
65 - 70	181	50,2	49	13,7	130	36,1	360
Total 14 - 70	3.017	15,1	7.619	38,0	9.391	46,9	20.026
71 and over	73	54,9	14	10,8	46	34,3	133
Total	3.090	15,3	7.633	37,9	9.436	46,8	20.159
Average age	45,3		36,8		38.7		39,0

Table 6. Overview of the agricultural economy according to crop/commodity produced (1979)

Crop/Produce	Acreage ha x 1000	%	P Production qli x 1000[†]	I Import qli x 1000[†]	I/P %	E Export	E/P %	Production area
Wheat	5097	18.4	130,700	35,680	27	-	-	**
Barley, Oats Rye	679	2.5	23,103	20,230	87	-	-	**
Mais	897	3.2	53,263	37,516	70	-	-	*
Pulses	272	1.0	3,663	1,147	31	-	-	**
Pasture	6402	23.5	1,487,000	-	-	-	-	**
Vegetable	725	2.6	159,000	-	-	10,012	6	*
Sugar beet	265	0.9	115,172	-	-	-	-	*
Tobacco	50	0.2	1,073	4, 050	-	4,391	-	*
Oil crops	25	0.1	460	14,352	-	-	-	*
Wine	1806	6.4	69,960	-	-	13,512	20	**
Olive oil	3954	14.2	4,400	-	-	-	-	**
Fruits	1331	4.8	76,801	-	-	17,130	22	*
Forest	6344	22.2	24,000	39,960	-	-	-	**
Livestock	-	-	29,176	20,156	69	-	-	**
Fish	-	-	3,578	2,885	80	-	-	-
Meat	-	-	-	6 524	-	-	-	-
Cheese	-	-	5,910	2,470	41	-	-	-

* = product prevalent on plains

** = product prevalent in hilly areas

Area where produce is prevalent

* plains

** hills and mountains

† qli = 100 kg.

that the most important group of imports includes cereals, meat, livestock and wood, and the most important exports are vegetables, fruit and wine. The first group (i.e. imports) deals with production from the hill and mountain areas, and the second group concerns production from the plains. Therefore, improved efficiency of agriculture in hill and mountain areas is required.

We can summarize the natural resource situation in Italy by looking at the morphology, climate, soil and agroecological zones. According to Table 7 and Figure 1, the total agricultural land area is mainly in areas of hills and mountains. The Table deals with farm repartition, but if we include the 2.577,000 ha. of state owned forest, then the percentage changes in the following manner: 21% plains, 39% hills, 40% mountains. As a consequence of this morphology we can emphasize significant differences between areas of plain, and areas of hill and mountains, differences in technological management and in productivity, as summarized in Table 8.

Table 7. Total farm area by land use and elevation (area give in ha) - 1979

	Crops	Fruits	Pasture	Total	Forest	Other	Total	%
Mountain	1,217,636	416,204	2,415,005	4,048,845	2,385,057	842,317	7,276,219	32
Hill	4,122,218	1,659,796	1,833,587	7,625,601	1,285,491	833,116	9,744,208	43
Plain	3,304,341	1,008,385	498,305	4,811,031	157,263	412,623	5,380,917	25
Total	8,654,195	3,081,385	4,746,897	16,485,477	3,827,811	2,088,056	22,401,344	100

The climate in Italy varies according to the following facts:

-- the length of Italy extending from the line of latitude of 36 degrees to a latitude of 47 degrees;

-- the Alps which divide Italy from the rest of northern Europe and which protect it from an inflow of cold air;

-- Italy's favorable location; two-thirds of its area borders on the Mediterannean sea;

-- a total width of not more than 250 kms between the Tyrrhenian and the Adriatic seas;

-- the Appenines which run from the north to the south of Italy.

As far as temperature and rainfall regimes are concerned, northern Italy is closest to Northern Europe, while central and southern Italy experience a mediterannean climate as shown in Table 9. One point that must be stressed is the sharp differences in temperature and rainfall regime between the north and the south of Italy, and from the Appenines to sea level. Besides this, the rough morphology is responsible for several topoclimates.

Concerning soil types in Italy, we can point out in short that the alpine areas originated from volcanic rock, whereas the Appenines have their origins in sedimentary and tectonic rock with a large amount of clay. These soil textures give us the agroecological classifications shown in Table 10. In Table 10 crop growth is summarized in Northern, Central and Southern Italy according to areas of plain or hill and mountain. For the most part agroecological classes belong to areas of hill and mountain, for example, some cereals, grapes,

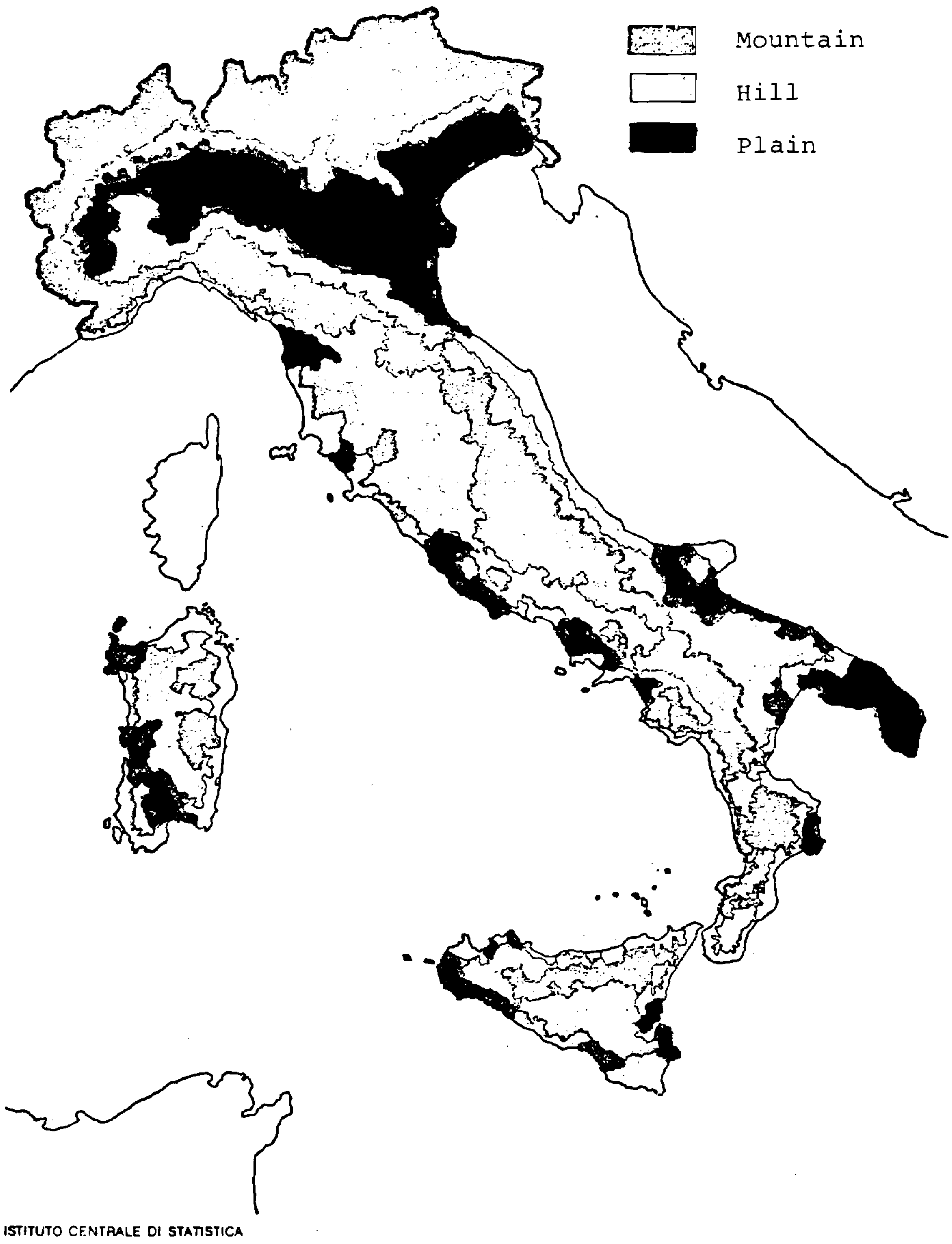

Figure 1. Mountain, hill and plain areas

Table 8. A comparison of hill, mountain and plain cultivation areas

	Hill and mountain	Plain
Soil preparation	***	*
Crop cultivation	**	*
Machinery	**	*
Microclimate	**	*
Soil depth	**	*
Drainage	**	***
Erosion	***	*
Water table pollution	*	***
Productivity	**	*

* - unproblematic

** - some problems

*** - serious problems

Table 9. Overview of Italian climatic conditions

	Temperature (°C)									Rainfall (mm)	
	sea level				1000 m						
	Jan.		Aug.		Jan.		Aug.				
	$\overline{M}$	$\overline{m}$	$\overline{M}$	$\overline{m}$	$\overline{M}$	$\overline{m}$	$\overline{M}$	$\overline{m}$	Year Average	Year	$\frac{W+S+A}{T}$
North	5.6	-0.8	29.8	17.5	3.9	-3.8	24.3	12.9	13.1	1100	0.65
Central	11.0	2.7	30.7	16.7	4.1	-2.1	24.9	13.2	14.9	852	0.80
South	14.4	9.8	28.6	19.6	4.8	-0.5	26.8	14.8	17.5	615	0.85

$\overline{M}$ - maximum temperature average

$\overline{m}$ - minimum temperature average

W - winter

S - spring

A - autumn

T - year

Table 10. Present agroecological distribution of crops

		Wheat	Durum wheat	Barley	Oats	Rye	Rice	Maize	Sorghum	Broadbeans	Chick-peas	Beans	Pasture	Clover	Alfalfa	Sulla	Potatoes	Vegetables	Sugar beet	Tobacco	Hemp	Cotton	Sunflower	Cola nuts	Peanuts	Grapes	Olives	Citrus fruits	Cherries	Apricots	Figs	Almonds	Hazelnuts	Apples	Pears	Plums
	M	*		*	*	*							**				**																			
North	H																									*								*	*	*
	P	**					*	*				*		**	**				*		*			*					*	*				**	**	**
	M	**		*	*	*							*				*												*							
Central	H	**									*	*			*		*									*	*									
	P							*	*			*			*				*	*			*		*											
	M	*			*								*				**																*			
South	H	**	**							*	**	**				**											*				*	*				
	P	**	*												*	*	*	*	**	**		*				*	**	*	*	*	*	*				

* - present

** - predominant

legumes, pasture land and so on.

Environmental problems can be classified as being of several different types:

- as a result of abandoned areas;
- as a result of agricultural mismanagement;
- as a result of a too intensive management of agriculture;

The first two problems are characteristic (typical) of hilly and mountaineous areas and are mainly related to problems of erosion (see Table 11), land slides, etc. The intensive management of agriculture occurs mostly in the plain areas, but is, in some cases, applicable to other areas too. At present problems of erosion are very serious and they are expected to become more and more pronounced and uncontrollable. The impacts of erosion on agriculture in the medium and long run could be disastrous in terms of fertility loss and a decrease in productivity.

With reference to the previous remarks we can draw the following conclusions:

- A need exists for a more balanced population density between the urban and rural areas, and more balance between nonagricultural and agricultural activities;
- Agricultural efficiency in hill and mountain areas must be improved;
- There is a need for the better land use and prevention of further environmental deterioration, especially in the hill and mountain areas.

It would be very beneficial to create a methodology in order to simulate the impacts of technology on agriculture and the environment, as well as the alternatives and effects of political choices.

THE CASE STUDY REGION

A region for case study has been selected based on the previous reflections on Italian agriculture and in view of the necessity of modeling agriculture in hill and mountain areas. The region, called Mugello, is located in Tuscany in the district of Florence (see Figure 2) and it covers the watershed of the Sieve river, a major tributary of the river Arno. It is representative of the landscape of the Appenines and the pre-Appenine valleys. It is classified as a mountaineous area according to the law 25.7.1952, clause 991 (see Figure 3). The surface area of the Mugello region covers about 104.000 ha. and altitude ranges from a height of 200 meters to 1400 (Mt. Falterona, the highest point) above sea level. The area extends for about 45 kms in length and 20 kms in width. The valley basin was formerly covered by a lake with a depth of 400 meters, which was responsible for the formation of some soils. In Table 12 we present an overview of different soil types, their age, etc. From the point of view of soil classification, we can distinguish 20 classes of soil type but, from an agricultural point of view, it is possible to divide the area into three main classes according to soil texture and soil depth. Deep clay soil and sandy-loam soil account for about 40% of the total area, and sandy soil of not great depth accounts for the remaining 60%.

The climate of the Mugello region (Table 13) is influenced by the Appenines; the temperature regime at an altitude of 200 meters differs from that of the Arno valley, where spring comes earlier. Differences in average minimum temperature can also be noted. These factors effect the length of the growing period required by crops, and is a limiting factor which must be taken into account in any attempts at agroecological classification. The time variability of

Table 11. Environmental problems

Causes	Effects: Short term (10-20 years)	Middle term (20-30 years)	Long term (over 50 years)	Conditions in Italy	Solutions
Runoff	- erosion - decrease in fertility	- severe decrease in fertility - changes in microclimate	- changes in trophic chain - changes in soil microorganisms - change in natural vegetation	**	- land management - channels - drains - ditches - ploughing technology - soil modelling - natural vegeation
	- landslide	- slope instability	- changes in morphology	***	
	- river flooding	- plain characteristics		***	
	- erosion	- changes in river bed - changes in coastal zone	- changes in marine vegetation and fish	**	
water/soil	- decrease in water /soil availability R/P	- changes in availability of sources	- changes in climate	*	
Pesticides	- decrease in pollination and useful insects	- increase in use of pesticides	- breaking of the producers/consumers chain	**	- biological pest control - breeding resistant species - decreasing productivity
	- river water pollution - commodities pollution	- changes in river ecosystems	- changes in sea ecosystems	*	
Fertilizers	- entrophication - thinning of the ozone layer (?)	- changes in sea vegetation - changes in climate	- changes in gas level of sea water, changes in climate	**	- crop rotation - breeding microorganisms of legumes - decreasing productivity

* - minimal problems

** - very diffuse problems

*** - problems everywhere

ISTITUTO CENTRALE DI STATISTICA

Figure 2 The case study region (Italy)

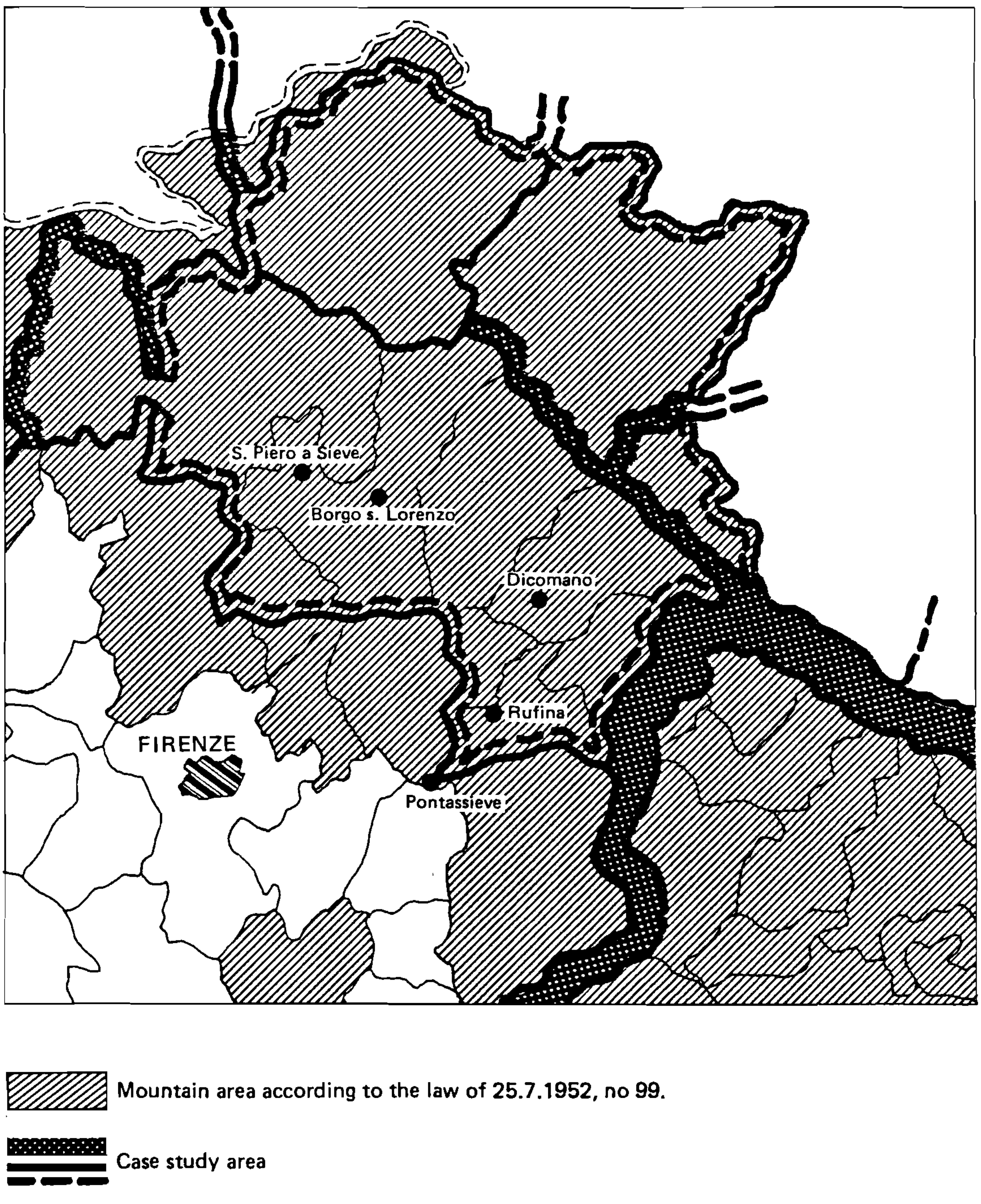
S. Piero a Sieve
Borgo s. Lorenzo
Dicomano
Rufina
FIRENZE
Pontassieve
Mountain area according to the law of 25.7.1952, no 99.
Case study area

Figure 3

Table 12. Soil types in the case study area.

Soil type	Age	Elevation (meters)	%	Land use	Depth	Slope	Erosion	pH
Sandy loam	Oligocene Miocene	> 500	0.2	forest pasture	*	***	***	≥7
Sandy	Eocene Miocene	200-500	0.4	vineyard cereals	*	**	**	≈7
Clay	Pliocene	400-800	0.08	cereals	**	***	***	5
Loam	Pleistocene	300-500	0.10	pasture	*	**	***	>7
Clay - lime	-	200-400	0.04	pasture forest	*	**	***	>7
Sandy	Pliocene	200-350	0.07	cereals	**	**	*	≥7
Sandy-loam	Miocene	350-450	0.03	cereals	*	*	*	≤7
Loamy-sand	-	200-400	0.08	cereals	***	*	*	- 7

* - very shallow/low/minimal

** - moderate

*** - deep/high/heavy

the average monthly temperature ranges over a period of 10 years between s.d. = + or - 1.5^{0}C and s.d. = +- 2.3^{0}C. The space variability is related to the altitude and the average is about 0.5 °C per 100 meters. During the night some temperature inversions occur. The rainfall regime is quite equally distributed in the area with peak figures occuring in the higher altitudes. The time variability of the monthly values of rainfall is quite high with a variation coefficient ranging from 0.5 to 1.0. The most frequent winds blow from the north-west during the winter and from the south-west or south-east during the summer months.

The river Sieve regime (see Table 14) is characterized by a very low discharge coefficient during the summer period due to low rainfall and high evapotranspiration; therefore, for annual summer crops corn irrigation is necessary. During the winter, autumn and spring the amount and intensity of the rainfall means that accurate land management is needed on areas of sloping land in order to prevent erosion and drainage in clay soils is needed to prevent land slides and to keep a sufficient level of oxygen in the soil to allow winter crop roots to respire.

The morphology of the watershed is represented by the valley floor land which has a slope ranging from between 0 and 2%, about 20% of the total, and by the hill area which ranges from between 250 and 650 meters in altitude with a slope of between 5 and 20%, about 40% of the total, and by the mountain area with a slope of 15% and above (Table 15).

The main crop grown in the clay and sandy soils of the mountain and hill areas is wheat, and in the sandy and sandy-loam soils of the mountain alfalfa, some barley and potatoes are grown. Vineyards are located in the hills on sandy-loam soils on slopes with a gradient of about 15% and which face the south, and on the valley floor we find summer crops such as corn or some vegetables in very deep alluvial soils which are irrigated.

Table 13. Climate of Mugello

		J		F		M		A		M		Ju		J		A	
		$\overline{M}$	$\overline{m}$	$\overline{M}$	$\overline{m}$	$\overline{M}$	$\overline{m}$	$\overline{M}$	$\overline{m}$	$\overline{M}$	$\overline{m}$	$\overline{M}$	$\overline{m}$	$\overline{M}$	$\overline{m}$	$\overline{M}$	$\overline{m}$
Temperature (°C)	200 m	10.7	-1.1	6.5	2.2	13.5	3.9	17.8	6.1	24.9	8.9	28.2	12.5	31.9	14.6	32.2	14.3
	1000 m	5.6	-2.5	5.8	1.0	7.8	1.2	11.4	2.9	17.8	6.1	21.7	9.8	24.6	11.8	24.5	12.0
Rainfall (mm)		111		114		101		98		100		80		39		52	

S		O		N		D		Year	
$\overline{M}$	$\overline{m}$	$\overline{M}$	$\overline{m}$	$\overline{M}$	$\overline{m}$	$\overline{M}$	$\overline{m}$	$\overline{M}$	$\overline{m}$
28.7	11.5	20.3	8.2	14.4	5.2	5.1	0.5	17.2	7.2
22.1	9.2	14.9	3.8	9.0	2.0	5.1	-1.0	14.2	4.8
91		142		162		131		1221	

Table 14. Hydrological parameters of the river Sieve (1931 - 1970)

	J	F	M	A	M	Ju	J	A	S	O	N	D	Year
Flow discharge (mm)	85	92	83	55	45	27	9	5	10	30	67	88	596
Rainfall (mm)	111	114	101	98	100	80	39	52	91	142	162	131	1221
Coefficients F/I	0.77	0.81	0.82	0.56	0.45	0.34	0.23	0.10	0.11	0.21	0.41	0.67	0.49
Flow (m^3/sec)	26.3	31.4	25.8	17.7	16.0	8.76	0.77	1.58	3.26	9.34	21.5	27.4	15.8

Table 15. Main produce of the Mugello region (1979)

	Acreage (ha)	%	Production (qli)	Production area
Wheat	8,634	8.3	191,775	**
Maize	1,357	1.3	78,710	*
Barley, Oats	1,750	1.6	35,300	***
Legumes	115	0.1	800	**
Vegetables	100	0.09	14,516	*
Potatoes	530	0.5	79,200	***
Wine grapes	10,215	9.8	241,165	**
Olives	10,841	10.0	33,585	**
Pasture	10,500	10.0		***
Forest	54,220	58.31		***

* - grown on plains

** - grown in hilly areas

*** - grown in mountainous areas

In the highest area of watershed there are pasture and forests on sandy soil of not much depth. The sharing of acreage is representative of the Appenine area and allows us to study the physical, biological and economic features of the Mugello region as a sample of a larger area.

The social features of the Mugello region (Table 16) have been characterized by the migration of the population from both the countryside to the villages and from the villages to the nearby town of Florence during the years 1951-1979. This urbanization phenomenon was spread over the whole of Italy and similarly a migration of the population from the southern regions to central and northern Italy occured. Changes in cultural behavior are related mostly to these movements and to changes in type of work and professional attitude. From an administrative point of view the region is divided into 12 districts (Table 17). The distribution of those employed in the agricultural, industrial and service sectors corresponds to national figures, and any major differences occur in the different districts. This change in professional activity has meant a sharp change in technology with a decrease in the total number of people employed in agriculture (see Table 18), increased use of machinery, (Table 19) and changes in the type of management (Table 20). These changes have had great impact on the type of agriculture, the use of energy, chemicals, machinery were accompanied by a low degree of efficiency due to the technical preparation, to the structure of the property, to the type of natural resources, needing a type of technology well adapted to areas with steep slopes, soils difficult to cultivate and climate. The last factor, climate, is characterized by sharp changes within a few meters. The transfer of technologies of the "green revolution" developed for use in plain areas or for gentle slopes has not been very successful, with the consequence that more and more people are being removed from the agricultural sector. As a result a large amount of land has been abandoned. Table 21 shows that 65% of the total area cultivated in the watershed was abandoned by 1973. This phenomenon, together with changes in technology, has resulted in land degradation such as erosion, land slides, changes in water cycles, forest fires, etc. We can assume that in the next 10 years a large amount of our natural resources will disappear (i.e. the land fertility which has been built up over the past several hundred years) if we continue this trend. We need to study new technologies, to find an optimum combination of productivity factors and a structure of property which allows us to find a way to support agriculture as a production and environmental activity.

Table 16. Population figures & fluctuations for Mugello, 1951-79

				Fluctuations			
1951	1961	1971	1979	51-61	61-71	51-71	51-70
89,633	77,572	73,429	71,102	-12,061	-4,143	-16,204	-18,531

Table 17. Employment (%) by activity sector, Mugello 1951-79

District	1951			1961			1971			1979		
	I	II	III	I	II	III	I	II	III	I	II	III
Barberino Millo	65.5	23.4	11.1	36.4	43.1	20.5	15.5	55.0	29.5			
Borgo S. Lorenzo	50.5	30.2	19.3	26.8	46.4	26.8	12.2	53.5	34.3			
S. Piero a Sieve	57.2	27.0	15.8	28.9	46.7	24.4	10.6	50.5	38.9			
Scaperia	67.1	21.5	11.4	41.8	41.2	17.0	18.5	59.8	21.7			
Vaglia	59.1	19.6	21.3	35.0	38.2	26.8	12.4	40.6	47.0			
Vicchio	74.4	16.8	8.8	52.6	32.6	14.8	26.3	47.3	26.4			
Dicomano	63.8	22.0	14.2	36.3	41,5	22,2	17.4	52.0	30.6			
Londa	74.6	16.0	9.4	53.9	30.6	15.5	23.8	51.6	24.6			
Pelago	56.5	30.0	13.5	34.6	45.8	19.6	13.5	56.3	30.2			
Pontassieve	58.3	27.9	13.8	33.1	45.9	21.0	12.2	50.7	37.1			
Rufina	49.4	38.2	12.4	32.9	48.6	18.5	15.3	57.5	27.2			
San Godenzo	68.6	21.1	10.3	45.1	33.9	21.0	24.4	44.8	30.8			
Total	60.5	25.8	13.7	35.8	43.0	21.2	15.0	52.6	32.4	13.5	46.2	40.3

Table 18 A. Labor force employed in agriculture in the Mugello region, 1951-79, by actual numbers and percentages

Districts	1951		1961		1971		1979	
	numbers	%	numbers	%	numbers	%	numbers	%
Barberino di M.	3,345	65.5	1,323	36.4	466	15.5		
Borgo S. Lorenzo	3,708	50.5	1,608	26.8	698	12.2		
Dicomano	1,245	63.8	560	36.3	263	17.4		
Londa	778	74.6	371	53.9	99	23.8		
Pelago	1,853	56.5	1,092	34.6	369	13.5		
Pontassieve	4,318	58.3	2,257	33.1	797	12.2		
Rufina	1,589	49.4	898	32.9	359	15.3		
San Godenzo	985	68.6	410	45.1	124	24.4		
S. Fiero a Sieve	949	57.2	366	28.9	129	10.6		
Scarperia	2,088	67.1	972	41.8	330	18.5		
Vaglia	1,087	59.1	575	35.0	144	12.4		
Vicchio	3,581	74.4	1,799	52.6	601	26.3		
Total	25,520	61.4	12,186	36.7	4,379	14.9	3,854	13.5

Table 18B. Changes in agricultural employment in the Mugello region, 1951-79, by actual numbers and percentages

District	1951 - 1961		1961 - 1971		1951 - 1971		1951 - 1979	
	numbers	%	numbers	%	numbers	%	numbers	%
Barberino di M.	- 2,022	-60.4	- 857	-64.8	- 2,879	-86.1		
Borgo S. Lorenzo	- 2,100	-56.5	- 910	-57.6	- 3,020	-81.2		
Dicomeno	- 685	-55.0	- 297	-53.0	- 982	-78.9		
Londa	- 407	-52.3	- 272	-74.3	- 679	-87.3		
Pelago	- 761	-41.1	- 723	-66.2	- 1,484	-80.1		
Pontassieve	- 2,061	-47.7	-1,460	-64.7	- 3,521	-81.6		
Rufina	- 691	-43.5	- 539	-60.0	- 1,230	-77.4		
San Godenzo	- 575	-58.4	- 236	-69.8	- 861	-87.4		
S. Fiero a Sieve	- 583	-61.4	- 237	-64.8	- 820	-86.4		
Scarperia	- 1,161	-55.6	- 597	-64.4	- 1,758	-84.2		
Vaglia	- 512	-47.1	- 431	-75.0	- 943	-86.8		
Vicchio	- 1,782	-49.7	- 1,198	-66.6	- 2,980	-89.2		
Total	-13, 40	-52.3	- 7,807	-64.1	-21,147	-82.9	-21,606	-84.9

Table 19. Changes in farm machinery, 1965-1975

	Tractors				Harvesters				Other			
	no.	cv	% no.	% cv	no.	cv	% no.	% cv				
1965	852	33,338			12	654			817	75,200		
1975	1,267	56,551	44.8	69	40	2,688	233	311	1,099	100,940	34	45

METHODOLOGY FOR THE REGIONAL CASE STUDY

The methodology being used at present is a preliminary outline, which will be described at its more detailed stage in a follow-up paper. Our methodological approach can be formulated in several modules:

-- crop module

-- environmental module

-- technology module

-- L.P. matrix or decision module

The Crop Module

The purpose of the crop module is to generate possible alternatives from a point of view of yield, taking into account soil, climate, fertilizers and pesticides. We have tried to summarize the main biological and physical processes leading to final production.

In a detailed classification of soil, we might distinguish up to 20 soil classes. We took 2 depths of soil into account. From a practical point of view, we tried to aggregate the soil according to texture and depth in a first approach using criteria from Tables 22 and 23 as a basis. We consider mainly problems of depth, drainage and aeration in clay soils, sandy soil, loam sandy soil, and sandy loam soil. We tried to aggregate soil types as shown in Table 28. We took 2 depths into account. As for climate (Tables 24 and 25) we selected two regimes of temperature, one between 200 and 500 meters, and one of 500 meters and above, and two exposures, namely North and South. Three slope classes were chosen (Table 26): between 0 and 10%, between 10 and 20%, and above 20%. Seven crop classes were selected: winter cereals, summer cereals, pasture, alfalfa, vineyards (grapes), olive trees, and forests. The module for the generation of yield operates on the basis of a period of ten days. The inputs are (Table 27):

-- time

-- temperature

-- soil water content*

-- radiation

-- crop resistance

-- L.A.I. (Leaf Area Index)

-- crop respiration

-- dry matter repartition

Table 20. Farm size (in ha) according to system of management, 1961-1970

	Year	0.5	0.5-2	2-5	5-10	10-25	25-50	50-100	100-200	200-500	500-1000	1000	Total
owner operated	1961	183	362	255	155	148	40	8	-	-	-	-	1,151
	1970	98	330	281	255	209	77	34	15	2	1	-	1,302
	Diff.	-85	-32	+26	+100	+61	+37	+26	+15	+2	+1	-	+151
owner managed	1961	51	125	198	315	338	174	90	66	43	16	5	1,425
	1970	6	33	60	85	154	120	95	73	65	15	7	713
	Diff.	-45	-92	-138	-230	-184	-54	+5	+7	+22	-1	+2	-712
sharecropping system	1961	-	129	690	1,952	832	117	3	1	-	-	-	3,724
	1970	1	56	300	591	251	23	7	2	1	-	-	1.724
	Diff.	+1	-73	-390	-1,361	-581	-94	+4	+1	+1	-	-	-2,492

Table 21. Abandoned areas in the Mugello region (1975)

District	Totally abandoned		Partially abandoned		Forest		Total		Crop land	Forest	Pasture	
	Surface	No.	Surface	No.	Surface	No.	Surface	No.	%	%	Surf.	No.
Barberino di M.	520.61	30	1377.42	125	242.76	22	2,141	177	83	17	-	-
Borgo San Lorenzo	1156.42	88	818.47	82	113.67	12	2,097	183	791	21	8.65	1
Dicomano	971.00	85	8.40	2	-	-	979	87	78	22	-	-
Londa	1269.71	57	640.36	45	-	-	1,910	102	44	561	-	-
Pelago	-	-	100.41	9	-	-	100	9	75	25	-	-
Pontassieve	425.72	35	799.17	88	3.00	2	1,236	126	98	2	7.40	1
Rufina	299.29	40	171.76	31	41.76	7	538	82	99	1	24.70	4
San Godenzo	3841.50	91	71.25	3	33.63	1	3,947	95	24	76	-	-
S. Piero a Sieve	263.84	24	667.24	64	-	-	931	88	100	-	-	-
Scarperia	149.22	5	813.45	66	-	-	974	72	68	32	11.50	1
Vaglia	177. 3	13	1098.57	103	27.80	4	1,303	120	76	26	-	
Vicchio	696.30	59	1375.44	175	1.50	1	2,134	242	68	32	60.76	7
Total	9770.75	527	7941.94	793	464.12	49	18,290	1,383	65	35	113.01	14

Table 22. Main soil qualities affecting yield

	Water regime	Drainage	Root depth	Temperature regime	Chemical fertility
Emergence	*	*			
Growth	*	*	*		*
Development	*			*	

Table 23. Relationship between soil paramaters and soil qualities

	Texture	Density	Thermal capacity	Hydraulic conductivity	Organic matter	ph
Water regime	*	*	*	*	*	
Drainage	*			*	*	
Root depth	*	*				
Temperature regime	*		*	*		
Chemical fertility					*	*

Table 24. Main climate qualities affecting yield

	Thermal regime	Water regime	Radiative regime
Emergence	*	*	
Growth	*	*	*
Development	*		*

Table 25. Relationship of main climate paramaters to climatic processes

	Air temperature	Soil temperature	Radiation	soil albedo	Soil Moisture	Air humidity	Wind	Evapotrans-piration	Rainfall
Thermal regime	*	*	*	*			*	*	
Water regime					*	*	*	*	*
Radiative regime			*	*				*	

Table 26. Main morphology characteristics affecting yields

	Slope	Exposure	Roughness
Emergence	*		
Growth	*	*	*
Development		*	

Table 27. Potential yield model

Inputs	Time span	Output per span	Total output
Temperature	Av. for 10	r_{c_1}	Y_p
Radiation	Av. for 10	r_{c_2}	
Soil water potential	Av. for 10	r_{c_3}	
LAI_{in}	0		
LAI_{DM}	10		
Respiration			

If $R_g > a$ we take into account only r_{c_1}, r_{c_2} and calculate

$$Y^{p_1} = \frac{CO_{2_0} - CO_{2_1}}{r_{c_1}} \cdot LAI - r$$

$$Y_{p_2} = \frac{CO_{2_0} - CO_{2_1}}{R_{c_2}} \cdot LAI - r$$

Then if $Y_{p_1} \neq Y_{p_2}$, we take the lesser of the two.

If $R_g < a$, we take into account $r_{c_1}, r_{c_2}, r_{c_3}$ and take the least of the three.

R_g	= global radiation
a	= constant
r_c	= crop resistance
Y_p	= net production
LAI	= leaf area index
r	= respiration

We compute the 10 days dry matter and repartition inputs on the basis of the function rc = f (T,W) and consider some constraints such as minimum temperature and radiation lower than $0.3 cal.cm^{-2}min^{-1}$ .Then we apply a reduction coefficient to the yield computed in this way accounting for two levels of fertilization, pesticides and irrigation obtained from statistical regressions.

The water content* input is computed in a separate subroutine dealing with rainfall, evapotranspiration, soil types, percolation and runoff for a period of 10 days. Respiration is a function of biomass and L.A.I. is f (t). Table 28 shows the possible alternatives which total 4032, but considering that in most cases we can aggregate still further, we can estimate the number of combinations as being approx. 500.

One of the points of our program deals with the setting up of a methodology for the collection of physical data and the establishment of a data bank which can be easily applicable to large land surfaces. This methodology concerns two main groups of problems: the first deals with the automatic acquisition of information on landscape, for instance, contours from conventional cartography. The second deals with the transformation of physical data gathered by aircraft and satellites. The data obtained from aircraft and Landsat which we can presently interpret are mainly related to land use from an agricultural point of view. The models with which we are currently working from HCMM and Tiros satellites are related to physical crop characteristics such as thermal capacity and water regime. We hope that this kind of data management methodology will enable the FAP Task 2 model to be used to a wider extent.

The Environmental Module

The environmental problems involved are:

- erosion
- transport of sediment into the rivers
- river flooding
- land slides
- impact of pesticides on river water quality
- impact of pesticides on agroecosystems and their long run effects

We will first investigate the problems of soil erosion occurring in abandoned areas and caused by agricultural practices. These are at present the most serious environmental problems throughout the Appenines. The environmental model is based on the computation of water balance at periods of 10 days.

The environmental module generates inputs (Table 29) for the crop module and erosion. The main inputs are:

- area
- radiation
- rainfall
- temperature
- soil hydraulic conductivity
- initial soil water content
- soil porosity
- L.A.I.
- depth of soil
- average field slope

The model computes the dynamic processes of runoff, infiltration, percolation and evapotranspiration. The soil loss is computed with a submodel related to runoff. The model will be implemented by comparing the values of average annual runoff and peak discharges within the parameters of the Sieve river regime.

Table 28. Number of possible aggregations involved in crop and environmental modules

	Soil Association	Climate	Morphology	Fertilizers	Pesticides	Irrigation	Erosion	Crops	
Number	3*	4*	3*	2	2	2*	2*	7	4032

* A further aggregation is expected, which will decrease the number of combinations to ≈0.1 total.

Table 29 Environmental model

Inputs	Output	Units
Rainfall Soil water content Upper limits soil water storage	Runoff	mm
Runoff Drainage area Slope Length-width ratio	Peak runoff	mm hr^{-1}
Radiation Temperature Crop LAI	ETR	mm
Soil hydraulic conductivity Capillary tension	Infiltration	mm

For every soil class we compute annual erosion, then, with an iterative run, the impacts on yield. This corresponds to the maximum level of erosion without land management of any kind. Then we make a hypothesis of a technology for the reduction of erosion to a level of 0.5 of the maximum using a suitable methodology, and the consequences are computed. An experimental farm belonging to the Ministry of Agriculture is located in the Mugello region for the purpose of studying problems of erosion and this provides us with a source of data.

The Technology Module

The purpose of the technology module is to generate a set of possible combinations of production factors such as soil types, climate, crops, fertilizers, pesticides, irrigation, soil losses, and machinery. For this purpose we need to know the techniques which are employed in the area.

The techniques can be classified based on operations to grow crops and to breed livestock. The technology module is composed of two parts: 1) the sequence of machinery and labor techniques for crop production; 2) the combination of soil type, climate and environmental impact techniques. We can combine these pieces to define technologies which are an aggregate of the foregoing factors.

The operations can be classified as in Table 30:

Table 30. Definition of technical coefficients

	soil preparation	soil cultivation	Harvesting	Production process	Livestock feeding	Units
Labor	*	*	*	*	*	hours
Fuel	*	*	*	*		tons
Machinery	*	*	*	*		hours
Fertilizers		*				tons
Pesticides		*				tons
Buildings				*	*	m^3

A Soil preparation
-- ploughing
-- discing
-- water management

B Crop cultivation
-- fertilizing
-- spraying
-- irrigation

C Crop harvesting
-- harvesting
-- drying

D Animal husbandry
-- feeding
-- building
-- milking

In operation A we currently select two alternatives, high power tractors and low power tractors; the same applies for operation B. In operation C two alternatives are selected in relation to the power of harvesting machines. In D we select two possibilities, grazing and zero-grazing. In every case we define the technique used with respect to:

-- labor
-- fuel
-- hours/ha
-- feed

and we have an estimation method for every technique to generate the coefficients.

According to the classifications in Table 30, we prepared a questionnaire to collect data on the more common techniques employed in the area in terms of combinations of machinery and inputs. The number of alternatives shown in Table 31 are mainly related to two classes of horsepower for tractors and harvesters and to two types of breeding, grazing and non-grazing. In this way we can generate the technical coefficient for every combination leading to a technology (see Table 32).

Table 31. Number of alternatives in techniques

	Soil preparation	Crop cultivation	Harvesting	Production process	Livestock feeding	
N	2	2	2	2	2	32

The Decision Module

The decision module, chosen according to Task 2 suggestions will be a model of linear programming (Table 32), by which we will carry out the optimization of the combinations of natural, social and economic resources according to a criterion function related to the basic intentions outlined in the previous sections such as to reduce erosion and pollution, to increase net returns for farmers and to increase both the amount of area which can be utilized and total production.

We have decided to consider the region to be modeled as a single large farm, neglecting for the present the problems related to the farm size and stressing the relationship between technologies, natural resources and the environment. The following elements will be collected for the whole region:

Table 32. LP Matrix

Input	Technology T_1 . . . . T_n	$\leq$	Con-straints
Fuel		"	C_i
Labor		"	.
Machinery		"	.
Fertilizers		"	.
Pesticides		"	.
Production		"	.
Soil loss		"	.
Buildings		"	. C_n

We define technology $T_i = c_i, s_i, m_i, p_i, c_i, t_i, f_i, i_i$ = the combination of soil type i, climate i, morphology i, fertilizers i, pesticides i, techniques i, productivity i. . . .

- -- population
- -- number employed in agriculture
- -- total amount of fertilizers, pesticides, water for irrigation
- -- machinery as type and as horsepower
- -- number of cattle, sheep and pigs
- -- buildings for breeding

The collecting of data for the whole area is possible because the figures are available from the Public Bureau of Agriculture. The dynamics of the processes such as erosion, could be simulated operating the LP matrix as a recursive model, when for instance, the soil loss will modify the classification of the soil types. In this connection in order to have a rough estimate of the magnitude of changes in natural resources, we will use separate models dealing only with physical units and directed only to a single problem.

Conclusion

This paper gives a general picture of the Mugello area and describes the program under way. During 1980/1981 the methodology to be employed was worked on in collaboration with the FAP of IIASA. It is hoped that local, regional, and national authorities, farmers' associations, and other local and national agencies will be involved in the study at a later stage.