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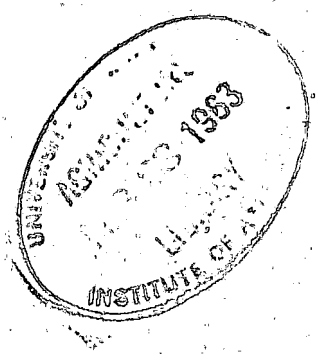

The Economics of Water Supply and Control: Greece Italy

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IRRIGATION IN ITALY

I. *General*

Irrigation in relation to physical environment

OUT of a territorial area of about 30 million hectares, the area in Italy devoted to agricultural and forest use is 27·8 million hectares of which 22·5 millions are devoted strictly to crop cultivation. Of this area 2,778,424 hectares (12·5 per cent.) are irrigated.

To appreciate fully the role played by irrigation in this country, it is necessary to bear in mind the physical formations and altitudes of the lands cultivated. It is well known that in Italy hill and mountain lands predominate, plains occupying only 32·3 per cent. of the territory. Obviously, the proportion of irrigated lands in the plain is much higher; it amounts in fact to practically half the agricultural area. The pattern, based on the large geographic-administrative divisions in which the national territory is divided, appears as follows:

	Distribution of area under irrigation		*Irrigated area expressed as % of agricultural area*	
	Ha.	*%*	*Total*	*Plain*
Northern Italy	2,133,329	76·8	27·3	60·4
Central Italy	231,477	8·3	5·7	59·5
Southern Italy	237,015	8·5	4·0	25·4
Islands	176,603	6·4	4·0	24·2
Total	2,778,424	100·0	..	..
Averages	..	..	12·5	49·8

It can be seen that irrigation is concentrated in both an absolute and relative sense in the north; the percentages for the central and southern zones drop sharply. This may be thought surprising in view of the hot dry climate that characterizes the southern zones of the Peninsula and the Islands (Sicily and Sardinia). The reasons are mostly physical, but in part also historical and economic. Firstly, while in Northern Italy plains cover 34·5 per cent. of the total area, in Central Italy the percentage drops to 8·6 and in the south and Islands to 15. Secondly, while the great Po plain of the north possesses, at least on the left bank of the river, a large quantity of flowing water throughout the summer, inextinguishable heritage from Alpine

snows and glaciers, only small supplies from streams and springs are available in summer in Central Italy and these dwindle to almost nothing in the extreme south and islands. The entire supply from all waterways south of a line that can be drawn across the Peninsula at about the level of Naples (including Sicily and Sardinia) amounts to less than one-quarter of the summer flow of one river north of the Po, such as the Ticino. It is easy to understand how such a shortage of water in summer restricts irrigation. Initiative was further checked by the fact that until recent decades almost all the plains of

TABLE 1. *Seasonal precipitation*

	Winter		*Spring*		*Summer*		*Autumn*		*Annual*	
	mm.	%	*mm.*	%	*mm.*	%	*mm.*	%	*mm.*	%
Milan .	182	20	253	27	217	23	282	30	934	100
Venice .	126	18	181	26	176	25	225	32	708	100
Bologna .	161	30	172	25	128	19	237	34	698	100
Rome . .	220	31	164	23	56	8	278	39	718	100
Naples .	292	34	156	18	80	10	323	38	851	100
Palermo .	339	46	144	20	30	4	222	30	735	100
Sassari .	245	40	145	23	22	4	208	34	620	100

central, southern and insular Italy were infested by malaria, due to hydraulic disorders which were remediable only by large-scale reclamation with its vast technical and financial requirements.

The various regions differ considerably with regard to climate. The central-northern regions come, according to the Thornthwaite classification, within the sub-humid zone with a water index of > 0. By contrast the southern ambient, situated between the parallels 37·5° C.–42° C. of northern latitude, comes within the sub-humid-dry climate; and some parts of it even within the sub-arid climate, with a water index around -20 and a water deficit that for a large number of crops is often above 600 mm. This results not so much from total annual rainfall as from its distribution—seasonally homogeneous in the north (approaching the typical conditions of Central Europe) and definitely irregular in the south, with the annual rainfall almost entirely concentrated in the autumn and winter months (Table 1). As a rule, southern rains are few and of extreme violence amounting to as much as 400 or 500 mm. in only 24 hours.

In summer there is much less difference in temperature between the north and south. In level zones the period June–August is everywhere the hottest and average temperatures do not show very marked

differences. There are greater differences in September when Sicily registers about 5° C. more than the Po Valley.

The pedological state of cultivated lands is another aspect which over time has contributed to the present pattern of irrigation. This differs remarkably from zone to zone and has great agronomic importance. In the Po Valley, for example, light permeable and often gravelly soils mark the left bank (north) of the Po, while heavy soils with a high total water capacity distinguish the right bank, some soils being formed partly by glaciation (Alps), the others by alluvia, mainly Pliocene (Apennines). In southern Italy and Sicily, besides soils of volcanic origin, which constitute the best lands, there are a few originating from limestone, poor in structure but fairly permeable as compared with the clay formations that constitute the greater part of the few plains. In Sardinia, soil break-downs derive from granites and basalts; they are rough and lack uniformity of texture.

All the above factors of climatic and geo-pedological (and to a certain extent historical) origin combine to split up the Italian irrigable ambient into large zones with diverse agronomic, economic and organizational aspects. These can be distinguished and classified as follows:

1. *Alpine Zone.* This comprises the wide plains of Piedmont and Lombardy on the left bank of the Po and the Venetian plain (excluding the low-lying lands at the mouth of the Po, in the province of Rovigo); also a few zones of West Emilia (provinces of Piacenza and Parma). The area brought under irrigation represents about 70 per cent. of the total irrigated area.

2. *Central Zone.* This goes from the River Po down to about the parallel of Rome; it comprises the Emilian plain on the right bank of the Po (minus the provinces of Parma and Piacenza plus Rovigo) and the regions (Tuscany, Umbria, Marches, Latium and northern Abruzzo) around the centre of the Apennine chain with their respective coastal plains.

3. *Southern Zone.* This comprises the south of Italy and the two large islands, Sicily and Sardinia.

Each of the zones indicated shows marked individuality, with regard both to agronomic aspects and to the general physiognomy of irrigation, from the viewpoints of supply and development of systems. It would seem opportune therefore to deal separately with the three aspects in question, rather than attempt a summary of the situation that might not adhere sufficiently to technical and economic realities.

Table 2 shows the distribution of the irrigation works that exist at present.

TABLE 2. *Irrigation effected at present in the three zones, by source of supply and type of system (thousands of hectares)*

Zone	Source of supply			Type of system	
	Streams	*Reservoirs*	*Ground waters*	*Gravity*	*Sprinkler*
I. ALPINE ZONE					
Piedmont	394	3	121	506	12
Lombardy	552	..	148	641	59
Veneto (excluding prov. of Rovigo)	384	20	64	365	103
Liguria	31	..	1	27	5
Emilia (prov. of Piacenza)	198	30	34	250	12
Total, Zone I	1,559	53	368	1,789	191
II. CENTRAL ZONE					
Veneto (prov. of Rovigo)	47	..	..	46	1
Emilia (excluding prov. of Piacenza)	88	..	18	99	7
Tuscany	36	8	17	36	25
Marches	18	4	13	28	7
Umbria	25	5	9	29	10
Latium	66	..	30	48	48
Abruzzo	20	2	7	25	4
Total, Zone II	300	19	94	311	102
III. SOUTHERN ZONE					
Molise	5	..	..	4	1
Campania	50	..	30	73	7
Lucania	9	1	..	10	..
Calabria	82	..	12	91	3
Puglia	..	..	21	19	2
Sicily	53	20	82	152	3
Sardinia	3	11	6	20	..
Total, Zone III	202	32	151	369	16
Total	2,061	104	613	2,469	309
	2,778			2,778	

The legislative and administrative framework

Before analysing the characteristics of the three zones it may be well to mention some of the concepts that govern legislation and regulation of water use. Save for a few regional differences, legislation is substantially uniform.

In a general way, provision for the use of water in agriculture is made by the Codified Act of 1933 (No. 1775) which regulates the

entire matter of water concessions. All waters of concern to other than the private sphere are declared to be public waters. A list of such public waters is held and continually brought up to date by the Ministry of Public Works. Use of such waters—whether for farm, drinking or industrial purposes—is in the form of a 'concession' on the part of this Ministry. This can be for what are called 'large derivations' (over 100 litres a second) allotted usually to public or private corporate bodies for a period of seventy years; or for 'small derivations', generally allotted to private individuals for a period of thirty years. For these concessions the state collects a rent, adjusted from time to time according to money values. Underground waters can also, for single zones, be declared of public interest, in which case their use requires a special authorization (for the sinking of a well) and subsequent concession on the part of the competent departments of the Ministry of Public Works.

Direct use of springs and streams by individual farmers is, however, limited. Use is partly controlled by such groups of farmers as are members of associations, of which the most frequent types are irrigation consortia and reclamation consortia. The first are usually associations enjoying private rights. Their official authority is limited specifically to the control of waters for voluntary users.

Far more important for such ends as administration of large irrigation systems (to which most of the installations in level zones belong) are the 'reclamation consortia'. These associations constitute 'public juridical bodies' that embrace obligatorily all landowners of a certain 'circumscription' (classification indicating land under reclamation by the State). This consists of either a single basin presenting hydrographic and hydraulic problems or a self-sufficient irrigable zone (generally some tens of thousands of hectares).

Organization is on an associative basis (with a duly elected board and chairman, formal constitution and so forth) but is subject to legislation that empowers the consortium among other things specifically to tax all the landowners in order to meet the cost of the works executed or defray definite expenditure for operation and management. The whole scheme is under the supervision of state agencies, particularly the Ministry of Agriculture.

The tasks of such 'reclamation consortia' include everything that in Italy comes under the term 'reclamation', that is to say, everything that can serve to put the district in good physical and agricultural order. Of most importance are the hydraulic works, and irrigation

plants, followed by roads, buildings and other agriculture works. Action is taken basically under a law which came into force in 1933 (No. 215), reinforced subsequently by a series of detailed regulations. At the present time more than half the national area is classified as under reclamation.

The great point of this legislation is the designation of a series of works—called public reclamation works—as eligible in the main for financial support from the state[1] while the consortia provide later for collection of the amounts (12·5 or 25 per cent. &c.) payable by the beneficiaries.

With regard to development of minor works on separate farms and works of land improvement, such as farmhouses, farm buildings, orchards &c., the law provides for contributions by the state to an extent of 33 per cent. in the north and 38 per cent. in the south (50 per cent. in particularly needy zones).

Thus, in line with existing regulations major collective irrigation schemes in Italy are nowadays state-aided as follows:

(*a*) for fundamental works (public), by a contribution that ranges from 75 to 92 per cent. (excepting a 100 per cent. contribution for big multi-purpose reservoirs in the south);

(*b*) for works to be effected on farms or for works involving communities in small zones of circumscription, by a contribution of between 33 and 38 per cent. (excepting a larger contribution towards such works as hill lakes).

[1] This financing ranges from 100 per cent. for fundamental interventions (such as river-bank stabilization, regulating reservoirs, reaforestation) to 87·50 or 92 per cent. in territories of southern or island zones, and 75 per cent. in northern zones for other big works such as drainage networks, inlet and distribution canals and road networks. Such 'public reclamation works' must be defined circumscription by circumscription in a master plan, which, prepared at the time of classification of the circumscription, serves afterwards as a guide in regulating the activities of the state and the consortium when implementing programmes. Generally public works are not carried out by the State direct but by the consortia through 'concessions' (after the project has been examined from a techno-economic standpoint and formal approval of the project itself and the amount bid for the carrying out of it have been obtained) on the part of the public administrations (Ministry of Agriculture and 'Cassa per il Mezzogiorno') dealing with the allocation of state contributions. These contributions are usually allocated by peripheral organizations of the Ministry of Agriculture, and 'concessions' have at times been restricted by the availability of ministry funds. Now, however, as a result of adequately financed schemes (such as the fifteen-year plan of the 'Cassa per il Mezzogiorno' for development of backward areas in the south, and the new five-year plan for agriculture—'Piano Verde') land-improvement contributions towards private undertakings and particularly irrigation works are distributed systematically. Projects drawn up by individual farmers are carefully studied by the competent officers of the Ministry and approved in advance. Subsidies become payable after the testing of the works. Sometimes low-cost loans take the place of subsidies.

For irrigation installations not of public interest (that is, belonging to individual farmers or groups of farmers, but in territories not classified as under reclamation), the state intervenes in the form and with the contribution mentioned in (*b*) above.

It is evident, from what has been said, that choice of the bases of irrigation programmes rests usually on an economic evaluation that has two aspects. There is an 'investment-return' balance-sheet that has reference to the national economy as a whole: on the one side lies the burden of all investment (of both the state and private persons); on the other, the increment in national net product (inclusive of secondary benefits and accruing effects) to be derived from the carrying out of the works.

A second balance-sheet applies to the individual owner of an agricultural holding, where on the debit side lies the burden of amortization and interest on the quotas payable by him for public works and for land investments; while on the credit side lies the increment in the income he receives from the land.

The first point of view is evidently essential for the choice of major irrigation schemes in the drawing-up of development programmes by state agencies. But the second viewpoint cannot be disregarded if one is to be certain that irrigation works on individual farms will also be completed and the waters rapidly utilized. Indeed, it is this second aspect that impels the state and its agencies (Ministry of Agriculture and 'Cassa per il Mezzogiorno') to use a graded system of contributions (appreciably increased in the last few years) both for public works and works on farms.

II. *Alpine Zone*

Geographical and historical aspects

The first of the three zones includes all the big classical irrigation systems of Italy. As already mentioned, these are based on the large supply of Alpine waters available in summer, partly from springs in the plains below, partly from the tributaries on the left bank of the Po—the Dora, Ticino, Adda, Oglio, Mincio &c.—and also from the pre-Alpine lakes and rivers which cross Venetia from the Adige to the Isonzo.

Most of the lands have a gravelly or other extremely permeable subsoil, which, in spite of the large supplies of water provided by lavish spring–summer precipitation, does not permit maximum

production from ordinary cultivation. This is why the populations of these territories have distinguished themselves over the centuries by construction of really important collective systems of irrigation.[1]

The projects in the north, especially those initiated by the free communes, led towards the end of the Middle Ages to an interesting evolution of rights pertaining to water and irrigation; and irrigated cultivation of crops adapted to local conditions. The Treaties of Roncaglia and the Peace of Constance having confirmed the complete freedom, *vis-a-vis* the emperor, of utilization of live waters; evolution of rights occurred under the communes who, sanctioned in their statutes the right of every citizen to lead water to the land, rendering the system operative by a right to carry water across the land of another, thus establishing a water servitude, which has been given the significant name of Magna Charta of Irrigation.

The second form of evolution is illustrated by the famous technique that governs the Lombard *marcita*. This is an irrigated permanent meadow, arranged in a series of double-winged strips, each with a slight uniform slope but in opposing directions, thus allowing a thin veil of water to pass continually over the surface of the meadow. As the spring waters in that region are warmer than the air, it is possible by delicate manipulation to achieve optimum crop conditions. The technique gives protection from snow and frost and permits a considerable production of grass even in the coldest season. In some zones the system was perfected by mixing sewage water from the city of Milan and other centres with the spring waters.

In the sixteenth and seventeenth centuries few schemes were started in the north owing to the political situation. But in the eighteenth century irrigation blossomed anew and agriculture made great progress, beginning to exploit, through irrigation, new summer crops introduced from abroad, particularly maize and clover. The century was charac-

[1] After a series of schemes had been carried out by religious orders round about the tenth century, work was begun on a large scale by the Commune of Milan (following the victory over the Emperor Barbarossa at Legnano in 1177) with excavation of the first big by-pass canal leading water from the Ticino, becoming then the 'Naviglio Grande' with a delivery of 64 cm. per second. The following century saw a whole network of canals, cut mostly by Lombard cities for navigation or for power, but all gradually and increasingly used for irrigation. The most important of these is the Muzza, to the right of the river Adda, begun by Lodi in 1230 and until the eighteenth century the largest irrigation canal in Europe, with 55,000 hectares of irrigated area and 1,285 kilometres of secondary and by-pass canals. In Piedmont, in the twelfth century, the cities of Vercelli and Novara began important irrigation systems, which were further developed in the fourteenth and fifteenth centuries. This last century also contributed the first big schemes effected by the Venetian Republic and by the Dukes of Mantua (Gonzaga).

terized, especially in Lombardy, by land and crop transformations on a grand scale aimed at solving the technical problems of using water on the land. At the same time there was an evolution of the land system through the break-up of large holdings into medium-sized farms with a type of farming that revolved round the dairy. Thus emerged the typical structure (*cascine*) which today characterizes the greater part of the irrigated plain north of the Po.

In Piedmont, moreover, in the same period, rice cultivation became regular and systematic. It was no longer a crop confined to exploitation of marshlands but one given a place in the farm rotation along with pasture grasses and other cereals.[1]

It must not be thought, however, that the construction of big schemes and the excavation of important canals mean immediate irrigation of the area dominated; almost always the construction of distribution channels and actual use of the waters on farms takes a time measurable in decades. In the case of the Villoresi Canal, for example, it was only after thirty years, in the period following the 1915–18 war, that a particularly torrid climate plus economic recovery furnished the impulse to bring the auxiliary works into operation with a consequent gradual irrigation of the area concerned. However, more or less slowly, all the level lands of the pre-Alpine territories, from Piedmont to the farthest point of Venetia, have found in irrigation the balancing factor for full production. Large quantities of water are applied principally to forage crops and meadows but also to those important summer crops, maize and rice.[2]

Techno-economic features

The economic balance of these irrigation works is based entirely on the low cost of the water used in farming. Supplies are almost always available from summer flows, so that no storage and but few deflective works are required. The big canals have long been amortized or, where necessary, completed by the state which exacts in return rents

[1] In the nineteenth century Piedmont also held the lead in waterways, the most important being the Cavour Canal (1863–6), fed by the Po, 110 cubic metres per second for the irrigation of 150,000 hectares. Other important works of the same period were: the bypass canal Ledra–Tagliamento (22·5 cm./sec.) in the extreme north-east of Venetia (1881); the Alto Agro–Veronese Canal (26·5 cm./sec., 1883); the Villoresi Canal (70 cm./sec.) which runs through the whole of Lombardy from the Ticino to the Adda (1884) and the Marzano Canal (25 cm./sec., 1890) also in Lombardy.

[2] Systematic efforts are being made to bring under irrigation the last marginal zones, typical of which are the terraces of moraines, situated just at the foot of the Alps; in such cases the land is generally used for the cultivation of fruit.

for use of the water. Distribution up to and on holdings is by earth-banked channels, the heavy seepage losses being unimportant in view of the quantity of water available and the ease of upkeep. Parcels of land under meadow or cereals are generally arranged in wide well-levelled pieces or in double-winged strips, and irrigation is effected with very large quantities of water—about 200 to 300 l./sec. Seasonal quantities register averages between 12,000 and 20,000 cm./sec. per ha., with peaks that are much higher, for example, for ladin clover meadows and rice fields. Naturally this type of use entails very heavy losses, both in distribution and on the land itself, so that there is much drainage and waste water, usually collected in an efficient drainage system and redistributed over zones at a lower level.

It can be said that without irrigation the prosperous agriculture of this region would not exist. However, on account of the traditionalism of such systems and the fact that they have constituted for so long the backbone of all farming in the zone, few figures are available for estimation of the profitableness of this irrigation. But if we refer to systems recently developed in Venetia, we can give as averages the following figures: the inlet canal and distributing mains represent generally in all a few metres per hectare; the distribution network around 30–40 metres per hectare, giving a cost per hectare of irrigable area of around 300,000 lire. Expenditure for management of collective irrigation amounts roughly to 4,000–5,000 lire per hectare per year. If the amortizations borne by farmers for their quota of public works and their repayment of loans for private works are considered, the overall amount payable by private individuals for irrigation (recent installations) works out at about 25,000 lire per hectare per year, and refers to a seasonal consumption of about 15,000 cm. per ha., equal to 1 l. per sec. throughout the season.

The use of irrigation in these parts results in an annual gross output of about 180,000 lire, about twice the value of output that could be obtained from dry-farming. Much higher, of course, are the increases obtainable from special development directed to establish irrigated fruit plantations in zones of poorest-quality land (moraines).

In conclusion we may say that this irrigated zone, called for simplicity's sake 'Alpine', does not lack works or projects in various stages of implementation. There are important ones in Venetia and also around Milan beyond the old canals. The area of such works and projects is estimated to amount to 200,000 hectares. They lie almost

entirely within reclamation circumscriptions and at least 80 per cent. form part of large-scale collective irrigation schemes which are frequently linked to hydroelectric plants in the Alps or to the big waterworks that regulate the pre-Alpine lakes.

III. *Central Zone*

Environment

The second zone in the classification is characterized by its geopedological structure, offshoot of the Apennine chain which, with its characteristic compact impermeable soils, reduces on the one hand the supply of river and spring waters in summer and, on the other, gives rise to agronomic situations quite different from those of the first zone. In fact the clay soils, which begin in the Emilian plain on the right bank of the Po, allow greater retention of the water from spring precipitations and occasional summer rains. Provided the land is well drained and ploughed deeply at the right time the compact soils of these territories allow the practice of an intensive dry-farming which is highly productive.

The progress achieved by this farming has depended more on reclamation and drainage than on irrigation. The difficulties of environment, however, be it in the lowlands near the mouth of the Po or in the small inland and coastal plains (maremma) of Tuscany, have considerably slowed down the process of reclamation. This, too, was begun towards the end of the Middle Ages but remained far behind the progress of irrigation north of the Po. In particular, only the modern use of power has allowed development of large-scale reclamation by the mechanical draining of lands below sea-level.

It was mainly on newly reclaimed lands that irrigation began some decades ago, and developed afterwards on a wider scale. It was a very different type of irrigation, however, from that north of the Po. It was of a type termed supplemental or restorative irrigation.

In relation to the typical rainfall of these zones and its distribution (see Table 1, for example, Bologna) and more precisely to the high water-holding capacity of the prevailing type of land, the water deficit over a normal summer rotation cycle can be estimated at around 2,000 cubic metres per hectare, corresponding to two or three waterings, even for very intensive farming systems with about 40 per cent. of the farm area under alfalfa, 20 per cent. under sugar-beet or tomatoes and other tracts under specialized cultivation of fruit. The deficit, however, varies according to the season. Often it may equal

only one watering. But in the more critical years only irrigation makes possible the outputs necessary for permanent balance of the farms.

Irrigation of this type does not lead to a revolution in crop systems, but is orientated to consolidate at a high level and render independent of seasonal variations an agriculture which is already highly productive. The water is particularly helpful for the cultivation of forage crops, especially catch crops and alfalfa, which form the basis of this type of farming, and also summer-hoed crops, such as sugar-beet.[1]

Techno-economic features

Obviously, this type of irrigation imposes some techno-economic limits. It does not allow very high amortizations of large basic works, nor, in particular, the expense involved in complete rearrangement of the farm layout for purposes of irrigation; and it needs, because of the compact nature of the soils, a very careful distribution technique, so as to avoid an excessive flow per unit of time. But as it is introduced usually into consolidated farm structures, it does not raise big problems of land investment rendered necessary indirectly by irrigation.

In practice, there are two solutions which best meet present-day needs: (*a*) sprinkler irrigation, usually by means of farm equipment that draws water from large distribution networks and (*b*) flooding of the drainage network in level areas during the summer to keep the land moist by raising the water table or to allow operation of the sprinkler equipment.

Both systems reduce the initial expense of introducing irrigation, avoid the high cost of preparing the land for distribution by down-flow or strip flooding and, at the same time, give to farmers maximum freedom of choice in timing their irrigation. This is most important. The first-mentioned solution is practically the only profitable one in mountainous or sub-mountainous zones. This second method is, of course, limited to certain zones situated in the plain and with certain soil characteristics, without excess of permeability. Sprinklers are often tractor-mounted on the same tractor that is used for ploughing.

In addition to these two typical methods, there are collective systems of irrigation dominating vast areas and supplied with sub-

[1] This applies typically to the Emilian plains south of the Po, and also for all regions of the Marches and the northern part of the Abruzzi, where the same types of clay soils abound, even though, as the lands are hilly, the general level of production obviously is much lower. On the south-west side of the Apennines (Tuscany), situations are less typical, owing to soils being more varied and the summer drought more accentuated, but still within the common framework of limited and mainly supplemental irrigation.

sidiary distribution networks, either with open conduits at surface level and flat-area gravity, or with pipe systems for joint sprinkler installations in hill zones.

The size of increments in production obtained through this kind of irrigation ranges, where forage is concerned, from 50 per cent. to 80 per cent. of what can be obtained from efficient dry-land cultivation; and for soil-enriching crops, from 50 to 70 per cent. But irrigation, even if limited to only a part of the farm, helps in these regions to improve decisively the whole farming enterprise.

The balance-sheet for this type of irrigation can be summed up as follows:

Expenditure for general distribution works (in great part borne by the state) is about 300,000 lire per hectare; and expenditure for farm distribution equipment is about 100,000 lire per hectare.

The amortizations and interest charges arising from this expenditure and payable by the farmer, amount to about 10,000–12,000 lire per hectare per year.

Expenditure for operation and distribution is from 15,000 to 25,000 lire per hectare. On the other side, the increments in gross output are of the order of 100,000 to 150,000 lire per hectare.

Hill lake irrigation

A particular feature of irrigation which enters into this picture and is therefore typical of this second irrigated zone, Central Italy, is that of 'hill lakes'. These consist of small reservoir-dams with earth banks usually not more than 10 metres high and capable of holding some tens and even hundreds of thousands of cubic metres of water. In them are accumulated the winter and spring rainwaters for utilization in the height of summer in the dryest zones of the Apennines where there are no other resources. Their construction is greatly encouraged by the Ministry of Agriculture. In the last decade about 2,000 have been completed, with an average per-unit carrying capacity of about 40,000 cubic metres (a total of 80,000,000 cubic metres dammed. Most of them are situated in the hill zones of Emilia, Tuscany, Marches and Abruzzi. Construction has been made possible and advantageous by use of the big crawler tractors common in those parts where the land is heavy, being usually on clay.[1]

[1] As a general indication, it can be said that the volume (in earth) of the earth bank of these lakes is around a quarter or a fifth of the volume of the reservoirs. The cost of the damming may be estimated as, on average, roughly between 100,000 and 120,000 lire per

The land so far watered by these lakes is about 40,000 hectares, an area not very large if compared with that of the big irrigation projects of the plain, but which nevertheless has considerable significance. The lakes give rise to a number of small oases scattered over territories that are otherwise quite dry. These oases make possible the production of quantities of forage which give balance to farms traditionally engaged in the cultivation of mixed crops, but which now must also include work and meat cattle.

Lastly, it should be noted that in this zone, and especially in parts of lower Emilia and the province of Rovigo, there are also rice-fields. They reflect above all the phase of transition in improvement of lands which, for various reasons (peat, salinity &c.) are irregular in feature. In such environments, generally the results of recent drainage, the rice-field has been, and still is, valuable in giving to the land a definite agro-pedological order. From a techno-agronomic point of view, this type of irrigation breaks away entirely from the average type prevailing in the 'Central Zone'. It approaches—with its high seasonal requirements of water, entailing precise and costly engineering and complete change of crop systems and consequently of revenue pattern—the type of irrigation peculiar to the Alpine zone.

Table 2 shows the figures for present irrigations in the 'Central Zone'. It is to be noted that big collective systems are to be found here also, though farm utilizations today are mainly from wells and hill lakes, especially in the Emilian plain. In this region vast works are under way in connexion with the Emilian–Romagnolo canal, which, deriving from the Po 68 cubic metres per second, will supply, together with ordinary seasonal irrigations, about 180,000 hectares of the East Emilian plain. Altogether, the areas in the 'Central Zone' where irrigation works are in process of realization may be estimated to comprise around 300,000 hectares.

IV. *Southern Zone*

Climatic and geo-pedological features

Passing from central to southern Italy (roughly below a line crossing the Peninsula from Rome), the picture changes again.

cubic metre of water stored, while that for distribution (generally sprinkler and often natural slope) works out at between 200,000 and 300,000 lire per hectare. Given the moderate seasonal quantities of water, which, being usually for supplemental forage irrigation, average about 2,000 cubic metres (losses are reduced to almost zero through piped distribution) the total cost of the works is around 300,000 to 400,000 lire per hectare with moderate operating expenses.

Climatic factors become pre-eminent inasmuch as the scarcity of spring–summer precipitation not only excludes the possibility of profitable summer cultivation of forage crops but also hinders cultivation of any other herbaceous summer crop. Irrigation therefore constitutes an innovation that brings in its train a whole series of revolutionary consequences for farm structures, labour contracts, and type and quality of marketable crops.

However, as already mentioned, the environment of the south and the two large islands (Sicily and Sardinia) rarely offers easy solutions of irrigation problems, owing to an almost total absence of streams and other sources of water in summer. Consequently, over centuries only a few areas endowed with springs or easily tappable ground waters have been able to develop water utilization for cultivation that usually hinges on vegetables and citrus fruits.

In fact, because of the irregular distribution of rainfall in Southern Italy and the lack both of streams available in summer and subterranean waters (due to impermeable geological formations) a vast irrigation programme is possible only when water can be stored in artificial reservoirs. This characteristic distinguishes the irrigation of the south from that of the north, where recourse to storage is exceptional and of secondary importance. On the other hand, the construction of reservoirs is certainly not facilitated by the geological and morphological features of the ambient (prevalence of clay and lamellated rock formations). Moreover, there is the constant danger of portions of land breaking away, owing to the severe erosions of hill and mountain lands. These have been forced by historical and social processes to carry an excessive rural population, which has wrested from the soil the much-needed grain. Even hills formed from Calabrian granites are disintegrated in the lower layers through physico-chemical action and movement in the rock formations of the earth's crust; and lands of the Tertiary (sandstone clays &c.) and overlying Quaternary Pliocene (clays, gravels and conglomerates) periods are by no means stable because of the continuing upward movement, which facilitates erosion and the filling-up of valleys. It is clear, then, that there is a close connexion between the nature of rock matrices and the climatic factors of pedogenesis on the one hand, and the water characteristics of the lands of the south on the other—particularly the lands of the valley bottoms and coastal areas recently reclaimed.[1]

[1] Of particular interest is the nature of the southern clays which, in spite of being of

In relation to the almost total lack of a spring and summer supply, seasonal consumptions of water range from 6,000 to 10,000 cm. per hectare, distributed over several months (six or more). From eight to ten waterings are required for compact soils of high moisture-holding capacity and twice the number for lighter-textured ones. This entails considerable use of labour and usually very high costs of distribution. Farmers therefore have always been inclined to choose crops of high value, mainly vegetables and fruits (citrus), even though this type of farming makes exceptional claims with regard to investment and outlay for cultivation.

Irrigation development programme for the south

The above picture shows clearly why, in the south, that is to say, in just the zone where it could have the greatest effect, irrigation has had only a very limited development (though there are exceptions such as the horticultural area around Naples, the citrus groves in Sicily, and the jasmine and bergamot farms in Calabria).

Only the post-war period has provided favourable conditions in a a series of evolutionary factors, political, social and technical, for far-reaching schemes for the development of irrigation in the south. Among relevant factors are the successful control of malaria, the progress made by hydraulic reclamation and the realization of land reform. This vast development scheme for backward regions launched between 1948 and 1950 is now in full swing. It is being financed by the Government with some partial aid from international organizations such as the Bank for Reconstruction and Development.

In the fifteen-year programme of extraordinary works for development of southern Italy, Sicily and Sardinia, entrusted in 1950 to the 'Cassa per il Mezzogiorno', the quota allotted to agricultural sectors amounts to 1,200 milliards of lire, equal to about 50 per cent. of the

the same parent material (marine) and period of formation (Pliocene), differ greatly from those, for example, of the Emilian plain on the right bank of the Po. There, the frequent frosts and rapidly evolving agricultural techniques have wrought deep changes, conditioning the lands through ordered processes and lavish applications of organic and mineral manures. By contrast, in the south by reason of the difficult drainage of plains, the violence and intensity of precipitation and winter floodings free, however, of frost—and also as indirect outcome of historical and hygienic conditions (malaria), the process of pedogenesis is still in a slow-moving phase with, as a primary consequence, a diffused, accentuated heaviness of the soil. Its elevated water-holding capacity, a characteristic which in the north represents a positive factor for purposes of accumulation in the active depth of the soil is, in the south and islands, a cause of saturation and asphyxiation on account of the over-sensitiveness of the land to excess of water, due also to insufficient watershed control.

whole amount earmarked for the plan. Thus agriculture has the predominant role in southern policy, though in this second phase, interventions in its favour are somewhat less pre-eminent.

In this programme, irrigation represents the principal element, which on the one hand calls for a whole series of infrastructural interventions (watershed improvement, hydraulic reclamation, construction of roads and power lines, setting-up of community services &c.) and on the other (with a view to the final utilization of the waters) capital investment on farms and settlement areas (houses, stables, ground-levelling operations, plantations, introduction of cattle, mechanization, &c.). The climate and environment are such that irrigation is the sole instrument capable of giving to southern agriculture not only the elasticity demanded by changing market needs and present-day patterns of productivity, but also the possibility of modernizing antiquated crop systems. The increments in gross output that will follow completion of the irrigation programme—increments ranging from three times to ten times the preceding level under optimum conditions as for citrus fruit culture—will obviously be reflected in increases in farmers' incomes, and particularly in farmworkers' incomes. This may check the drift of labour from mountain and hill farm, which the south is witnessing like all territories undergoing development. A particular point is that irrigation permits the smoothing down of the peaks which at present characterize the seasonal work patterns of southern farming and which are the main cause of chronic under-employment and consequent low incomes.

Table 3 shows total planned interventions under the fifteen-year (1951–65) irrigation plan for the south. On completion the irrigable area (inclusive of wastes and partial systemizations) will be about half a million hectares.

Technical features of works

Supplies of water for irrigations will be obtained in part from rivers (concentrated principally in Abruzzo and Campania) and to a moderate extent from underground sources. Mainly, they will be waters accumulated in reservoirs and will amount altogether to around 2 milliard cubic metres.

Given the configuration of the territory, formed of hundreds of independent basins with few and limited plains, the installations provided for by the scheme are very numerous and notably small (115

with an average area of 4,350 hectares). There are some, however, that differ from this general picture, which are complex and of fundamental importance, such as those of the Basso Volturno (27,000 ha.); the Apulian plateau (about 30,000 ha.) and the scheme on the right bank of the Ofanto (13,000 ha.) in Apulia; the Bradano and Metaponte works along the Ionian arc (32,000 ha.); the plains of Sibari (18,000 ha.) and Rosarno (12,000 ha.) in Calabria; the plain of Catania (40,000 ha.) and the Belice and Carboi scheme (25,000 ha.)

TABLE 3. *Plan of irrigations of the 'Cassa per il Mezzogiorno', 1951–65*

Region	*Water supplies*[1]		*Area brought under irrigation (hectares)*
	Streams cm. per sec.	*Reservoirs (millions of cm.)*	
Lazio	18,442	..	33,792
Abruzzo-Molise and Tronto	18,245	88·94	39,735
Campania	56,757	9·50	82,791
Puglia	4,580	363·00	57,419
Basilicata	3,200	140·00	33,290
Calabria	33,380	135·84	56,800
Sicily	7,459	406·58	102,637
Sardinia	38,920	784·40	93,752
	180,983	1,928·25	500,216

[1] Other than ground water supplies.

in Sicily; the Campidano (30,000 ha.) and Nurra (16,000 ha.) in Sardinia.

Generally the interventions provided for under the 'Cassa' Plan involve completion of full-scale schemes and ancilliary works, from reservoirs down to subsidiary distribution networks and transformations of land and farming systems. There are two exceptions, however—the two major projects: the Fortore in Capitanata and the Campidano of Cagliari. While the projects of each are on a scale of around 80,000 to 100,000 hectares, the 'Cassa' Plan provides for only about one-quarter. But the development of these schemes is not likely to be held up, in so far as the gradual financing of them is provided for under other programmes, such as the 'Piano Verde' (Green Plan) and 'Piano di Rinascita della Sardegna' (Plan for the Re-birth of Sardinia).

Concerning the plan for accumulation of water, nine reservoirs have now been completed and are together capable of supplying 980 million cubic metres of water for irrigation. Eight more are

in an advanced stage of construction with a capacity of 504 million cubic metres and another ten with a capacity of 300 million cubic metres are awaiting bids from contractors.[1] By the end of 1960 132 kilometres of large inlet canals, 1,429 kilometres of distributing mains and 5,289 kilometres of ramifications, covering about 150,000 hectares, had been completed.

Inlet constructions comprise mainly open conduits at surface level. However, there are many underground channels of considerable importance either on account of length, delivery volume or difficulties of execution. The canals of distribution networks are mostly of cement, pre-fabricated in 6-metre lengths, laid on cement supports. The networks of group sections serving individual farms have generally a delivery volume of around 50 to 60 litres per second, which corresponds to the average quantities of water available for distribution to southern farmers. Considerable use is made of mechanical regulating devices in networks, with only limited applications of complete systems of regulation from below. The inflow to the group sections mentioned, which always occurs through small reinforced-concrete canals, reaches each individual farm (save in cases of exceptionally fragmented properties) by a separate intake; the length of networks is thus brought up to between 50 and 70 m. per ha. and in some cases very much more. The preparation of the land to receive the irrigation water is generally by levelling for forage cultivation, digging ditches or furrows for vegetables and industrial crops, and dividing the area into basins for citrus plantations. In some schemes not all the surface of every farm is 100 per cent. irrigable; in extreme cases part-irrigations amount to as little as 50 per cent. of the whole farm.

[1] This involves a series of works comprising a whole range of constructions, with very frequent earth banks (mixed granulometric) in relation to an exceedingly varied series of geo-technic conditions. These reservoir-dams come usually within the framework of seasonal integration in more complicated systems in which streams play a part. This explains price disparities and certain peaks in unit volume cost of damming. Moreover, although these reservoirs have irrigation as their main objective, this is generally associated with other objectives—in the first place, hydraulic systemization, which necessarily utilizes a part of the reservoir's capacity, while another part is gradually filled by soil deposits from eroded lands above. Other aspects of co-ordination are the possible utilization of the water for drinking purposes or for industrial use in newly developed zones. Multiple services form the objectives of numerous schemes, which sometimes derive irrigation services from plants installed for power production. In various cases, while big problems of seasonal (and interannual) regulation and dual-purpose utilization have been solved by adequate development of storage facilities, wide use has been made of small equalizing reservoirs below power-stations to ensure steadiness of irrigation over the 24 hours or period of days in spite of the concentration of discharges necessary for the functioning of power-stations doing 'peak' service.

Although the system of distributing the water by gravity through pre-fabricated channels characterizes the greater part of present programmes, among others of importance are piped systems, using collective sprinkler distribution. In this field, some of the schemes being realized, such as that of the Nurra in Sardinia which will dominate over 20,000 hectares, are amongst the largest and most complicated in Europe, due partly to the considerable research effected with regard to adaptation of distribution to requirements and rational use of natural slope between height of dam and level of irrigable land. The Fortore scheme in Apulia is also based on natural slope sprinkler distribution over 60,000 hectares of the Apulian plateau. In addition, very wide use is made of fixed and mobile sprinkling equipment of farm type; the water is pumped either from wells or from the canalized networks of big collective systems.

Agronomic aspects

From information collected, the crop distribution of areas irrigated during the last season appears to be as follows: horticultural crops 34 per cent.; industrial crops (maize, sugar-beet) 23 per cent.; forage crops 27 per cent.; citrus fruits 12 per cent.; rice 4 per cent. The pre-eminence of horticultural crops is very evident. It is due to the nature and situation of southern irrigated lands, which allow at the same time maximum intensiveness of labour use and returns, and maximum adherence to market possibilities. A more difficult problem is the development of livestock husbandry (although some excellent examples of stockbreeding have been provided), while a satisfactory contribution has been made by sugar-beet culture. This has responded well to the southern irrigated environment and consequently many new sugar factories have sprung up. Lastly, in some 'difficult' zones, rice has helped to solve the cultural problem.

The Ministry of Agriculture and 'Cassa per il Mezzogiorno' follow up construction of works by actions directed to ensure technical and entrepreneurial advancement. They have instituted experimental farms as a background for practical demonstrations, summer courses for workers and technicians, agricultural schools for boys and about 100 advisory centres.

With regard to orientation of production, horticultural crops are recognized as being the most rational and most responsive to local conditions. But at the same time both technicians and planners are anxious about the scarcity of forage crops and the consequent limita-

tion of cattle-rearing in the irrigated zones, especially those with a difficult pedological structure and intrinsically low fertility. It is generally agreed that the pedological factor is one of the most decisive for rapid water utilization, inasmuch as light warm soils are usually more quickly brought into use for the growing of vegetables and fruit trees, while compact clays present difficulties for land use and give rise to delays in establishing new plant growths.

With regard to effective development of irrigation in the areas covered by distribution networks, it may be said that roughly 50 per cent. of the utilization is achieved fairly rapidly, that is, in a space of five or six years. But progress in the remaining area is very much slower.

Another important element in hastening or delaying fruition is provided by the market situation. It is well known that even small additional quantities of crops in zones devoid of trading facilities and traditions provide such falls in prices that the entire profit is removed from the harvest. Pioneers are discouraged and the majority of farmers thrown into confusion. This occurs frequently with crops requiring intensive cultivation (tomatoes, artichokes &c.). Problems in the marketing of meat and milk may also constitute, for distant and not easily accessible zones, a preclusive factor for development. Such problems are kept very much in mind in the Plan for the South, which provides facilities and financial aid for the setting-up of food processing and preserving plants and encourages the activities of co-operatives, consortia &c. But in this field, the associative spirit (which is entirely lacking in the environment in question) and entrepreneurial and trading abilities are not easily improvised, so that these market difficulties are often present in an acute form from the very first phase of the development of irrigations.

Cost of works

With regard to the costs which characterize the 'Irrigation Plan of the South', the chief differentiating factor in schemes is constituted by whether or not they involve the construction of reservoir-dams. It can be said that total per-unit cost of such reservoirs in relation to water dammed is generally lower (between 30 and 50 lire per cubic metre) for large ones (over 100 million cm.). For smaller reservoirs, it reaches occasionally 150 lire per cubic metre when they present construction problems. If an average per-hectare consumption (inclusive of losses) of 7,500 cubic metres per season is considered, the

average cost per hectare of any necessary reservoir can be estimated at around 400,000 lire per hectare. This means (adopting a rate of 5 per cent. for interest and 3 per cent. for maintenance expenses) a reservoir cost incidence of 21,200 lire per year per hectare irrigated.

The cost of the inlet and distribution network amounts to about 500,000 lire per hectare irrigated. Hence there is an annual interest burden of 25,000 lire a hectare, to which must be added an average annual cost of 10,000 lire for maintenance operation and modernization.

Altogether, taking into account the facts that the reservoirs in the territory in question are entirely chargeable to the state and that the other irrigation works are likewise chargeable to an extent of about 90 per cent., annual cost for a hectare of area irrigated is as follows:

TABLE 4. *Irrigation Costs*

	Total cost (referred to the national economy)	*Cost to the proprietor*
	Lire	*Lire*
For reservoirs { interest on investment	20,000	..
For reservoirs { management	1,200	1,200
For works of distribution:		
interest on investment	25,000	2,500
amortization, upkeep and management	10,000	10,000
Total	56,200	13,700

Costs rise rapidly if pumpings are introduced into gravity distribution networks. Apart from the cost of electric power (12–14 lire per Kwh.) the management cost is doubled when the water is raised only 10 metres; this cost rises to 20,000–25,000 lire per hectare when the water is raised about 30 metres.

These costs include, of course, only a small part of the burden the farmer has to shoulder in carrying out irrigation. Another heavy expense is involved in the preparation of the land; this can be estimated at around 150,000 lire per hectare merely for earth-moving operations. The state contributes to this to the extent of one-third: the annual burden for interest and amortization is therefore about 7,500 lire per hectare. It is the heavy cost of land preparation and the reluctance of farmers to face it that makes sprinkler irrigation appeal even in cases where theoretically it would appear to be more costly. Moreover, in the south, as repeatedly stated, irrigation implies a revolution in crop

systems, with extremely severe effects on old farms, involving investment in workers' dwellings, farm buildings, machines and plantations, all of which absorb very impressive sums in cases of intensive farming, such as citrus-fruit cultivation.

Economic balance-sheet

Owing to the extreme variety of situations, it is very difficult to draw up a complete balance-sheet of such transformations on southern farms which are rendered irrigable. A rough average may be indicated, with reference to wholly reclaimed and transformed zones, by the following:

TABLE 5. *Costs and Returns*

	Total investment chargeable to the national economy (lire per ha.)	*Total costs chargeable to proprietor (lire per ha.)*
A. *Cost of transformation*		
For large reclamation and irrigation projects	800,000	80,000
Farm transformation	700,000	440,000
Total fixed investment	1,500,000	520,000
Stocks and working capital increment	200,000	180,000
Total cost of transformation	1,700,000	700,000
B. *Returns*		
Average gross saleable output after transformation	400,000 per ha. per annum.	
Before transformation	80,000 ,, ,, ,,	
Gross saleable output increment	320,000 ,, ,, ,,	
Farm income increment	50,000 ,, ,, ,,	

If, however, one moves from the average situation pertaining to irrigated cultivation of mainly industrial and horticultural crops to a consideration of the cultivation of higher value crops, such as citrus fruits, the figures for both series increase greatly. As an indication, Table 6 gives average figures derived from a recent study on irrigated lands in Sicily and Calabria.

A method of irrigation that deserves separate mention is that of the sprinkler, which in southern programmes is rapidly increasing for three main reasons: (*a*) the technological progress that constantly attends installation of this system; (*b*) the psychological appeal it makes to the young, who prefer mechanized to manual work on the land; (*c*) the shifting of the weight of the initial expense burden to that of an operation spread over the year.

TABLE 6. *Global investment and returns (lire per hectare)*

	High-quality citrus groves in poor topographical environments irrigated generally with well water	*Medium-quality citrus groves situated on level lands recently reclaimed*
A. *Costs of transformation*		
Cost of big reclamation and irrigation works outside of farm boundaries	500,000[1]	1,000,000[1]
Preparation of land	600,000	200,000
Farm irrigation works	300,000	100,000
Buildings	150,000	150,000
Tree plantations	800,000	400,000
Total	2,350,000	1,850,000
B. *Returns*		
Product (tons)	20–25	20–30
Per-unit price (lire per kilogram)	48–60	27–40
Value of gross product	1,200,000[2]	800,000[2]
Expenditure for fertilizers, water &c.	300,000	100,000
Net product	900,000	700,000
of which:		
Labour	160,000	160,000
Taxes &c.	100,000	60,000
Farm income	640,000	480,000

[1] Of which nine-tenths are chargeable to the state.

[2] As compared with gross product values of generally below 100,000 lire per hectare before irrigation.

A recent detailed analysis (*Associazione Consorzi di Bonifica* by Berté) provides the following information.

In large-scale sprinkler systems, plants are preferably semi-mobile of medium pressure (water height 30–40 metres) with a total head of between 50 and 70 metres in addition to what may be needed for topographic delivery; the fixed network required is about 50 metres per hectare apart from the 7 metres per hectare of portable piping which is farm equipment.

In windy zones low-pressure sprinklers are advisable; in fact, farmers tend to adopt these even in the absence of experimental data.

The seasonal volume per hectare for normal irrigations is around 3,500 cubic metres per hectare.

In areas where the water must be raised, the reduced amount of power used as a consequence of the smaller per-unit water consumption soon counterbalances the cost of raising the water.

Taking into account expenditures for installation and operation, there is not usually an appreciable difference in cost between electrical and thermal power.

The capital cost of semi-mobile group installations is about 230,000 lire per hectare, of which 170,000 is for pipes and accessories.

The annual balance-sheet, therefore (assuming a total head of 60 metres, a consumption of 3,000 cubic metres per hectare per season at a cost of 14 lire per Kwh), is estimated as follows:

	Lire per hectare
General and distribution expenses—excluding cost of power	3,500
Cost of power	10,400
Upkeep and repairs	8,400
Total	22,300
5 per cent. interest on capital invested	14,000
Total cost	36,300

giving a water cost of 12·10 lire per cubic metre.

Therefore, if one considers smaller per-unit consumption (inclusive of losses) and the land-preparation expenditure that may be regarded as saved (50 per cent.), it is easy to see that sprinkler irrigation can in the end cost the farmer less than irrigation by gravity methods. The negative factor of wind, however, should be remembered, as it greatly increases consumption even with this system, given the heavy losses from evaporation and plant transpiration.

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FIG. 1. The present state of irrigation in Italy.

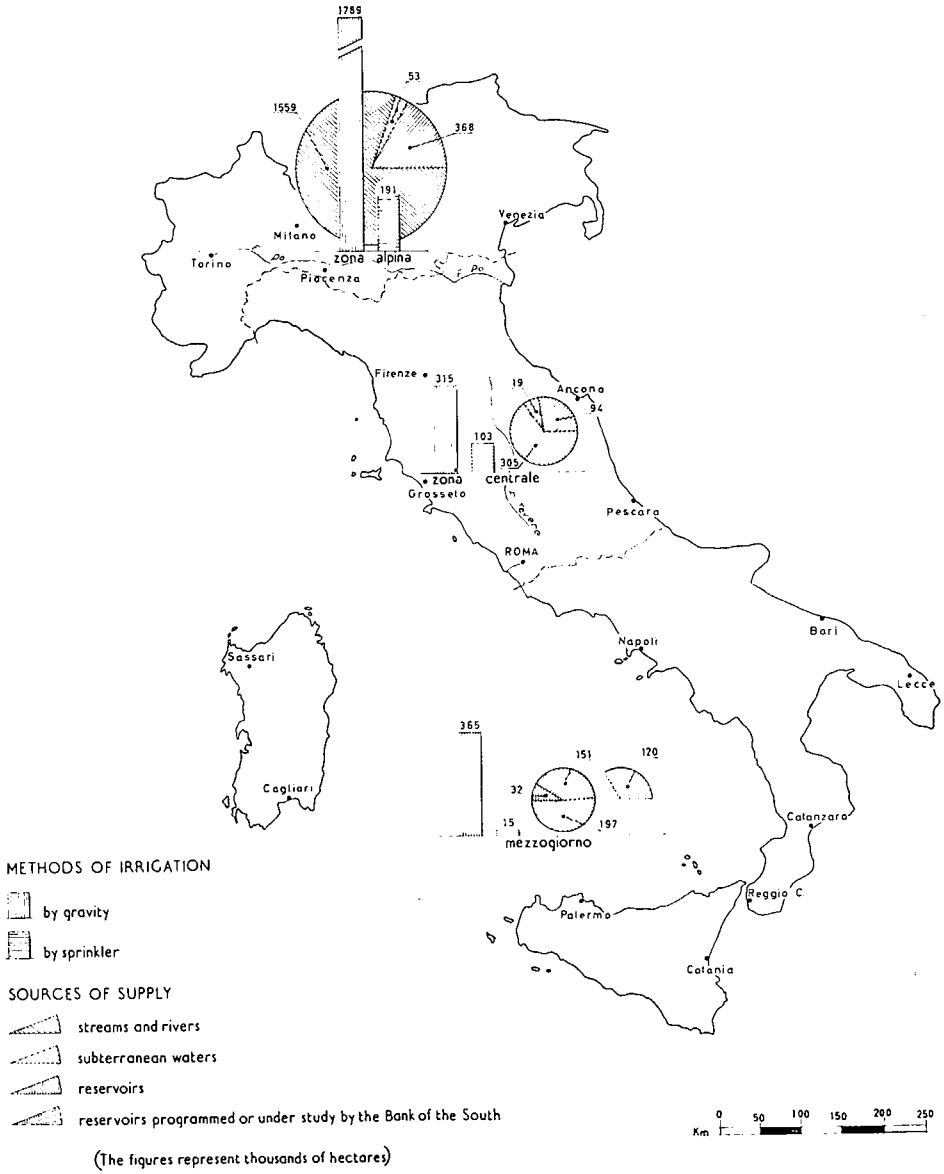

FIG. 2. Sources of supply and methods of irrigation