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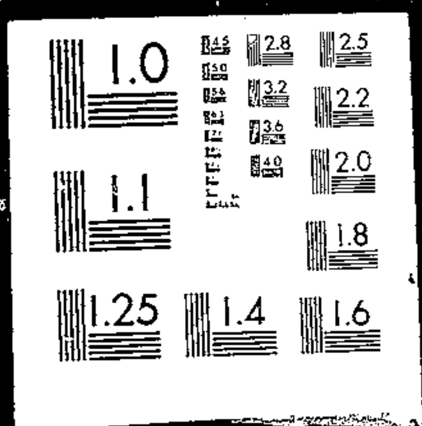

FOREIGN AGRICULTURAL ECONOMIC REPORT NO. 85

FORECASTING WHEAT PRODUCTION IN TURKEY

U.S. DEPARTMENT OF AGRICULTURE • ECONOMIC RESEARCH SERVICE

ABSTRACT

The study develops a method of providing preharvest forecasts of Turkish wheat production. The basic approach was development of a mathematical relationship between weather conditions during different parts of the growing season and wheat yields. Other relationships were developed to explain variations in area planted and in total production. These relationships gave a reliable set of forecasts for 1969-71; however, statistical tests on the relationships indicated that, normally, errors larger than those obtained would be expected. The study indicated that the most important variables affecting production in any one year were, in addition to area planted, January, February, and May weather conditions and the level of fertilizer application.

Key words: Turkey; wheat; weather; forecasting.

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SUMMARY

Variation in the quantity and distribution of rainfall in Turkey's main wheat producing area causes wheat output to fluctuate widely from year to year. A mathematical model that emphasizes the relationship between weather factors and wheat yields provides a comparatively reliable preharvest forecast of wheat production levels.

To develop the model for forecasting wheat production, forecasting equations for yield and area planted were estimated. Statistical analysis of the variables affecting 1948-68 wheat yields indicated that weather conditions during January-February and May-June have a significant impact on yields. Another variable of major importance is the level of fertilizer application. Use of these variables provided an equation that gave yield forecasts within an acceptable range of variation.

The equation for forecasting area planted was based on variables for area planted in the previous year, wheat price during the previous year, and trend. Only area planted in the previous year proved to be statistically significant. The price variable was kept in the equation, however, to conform with economic logic, which says that price influences shifts in area planted. For 18 of the 21 years under analysis (1948-68), the area equation provided estimates that differed from reported area by less than 5 percent.

The independent estimates from the yield and area equations were combined to provide estimates of wheat production. In addition, a forecasting equation that estimated production directly was developed. It used essentially the same set of variables that were used in the yield and area equations. Comparison of production estimates indicated that both methods gave estimates that had relatively the same degree of accuracy. Both methods gave a reliable set of forecasts for 1969-71--years outside the range of input data. However, statistical tests on the relationships indicated that, normally, errors larger than those obtained would be expected.

An aridity index was used to capture the effect of weather. Use of the index has an advantage over use of a precipitation variable alone because the index indicates that temperature, through its effect on evaporation, also affects availability of moisture for plant growth. Average monthly precipitation and temperature data were used to calculate the index. Two- and 3-month indexes were calculated from the monthly data. Tests involved using the precipitation variable alone, the monthly indexes, and 2- and 3-month combinations.

FORECASTING WHEAT PRODUCTION IN TURKEY

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INTRODUCTION

Turkey is among the world's leading wheat producing countries, ranking sixth in production in 1968. However, Turkish production levels are highly variable, primarily because of weather conditions on the Anatolian Plateau, the principal wheat production area.

This study reports on the development of a quantitative model to determine the relationship between climatic conditions and wheat production in Turkey. The model was designed to have the capability of providing reliable forecasts of the size of the Turkish wheat harvest earlier than do currently available reports. Such forecasts would be helpful to officials responsible for planning wheat shipments to Turkey.

Originally, the model was designed to be applicable only to the Anatolian Plateau. However, under restrictive definition of the Anatolian Plateau, only Turkish agricultural regions 1, 8, and 9 (see fig. 3, p. 6) would be covered. As the study developed, it became obvious that little additional effort was required to extend the calculations to a national basis. The main benefit of the extension was that it facilitated use of basic input data on a national basis rather than on a regional basis.

The study concentrates on the relationship between climatic factors and wheat yields. Although wheat harvesting in Turkey may continue into August, the analysis was limited to weather variables that stopped with June data. Temperature and precipitation were the only weather variables tested. A more complex model would have tested additional variables such as temperature extremes, soil temperatures, and wind speed.

Most of the input data were for the 1948-68 period. Exceptions included selected tests of weather variables and wheat yields for 1934-68. Data limitations prevented extending the whole study to the longer period. Although it appears that for some months, weather has very little influence on wheat yields, there is no arbitrary way to decide which months they are; consequently, all 12 months were included at the onset of regression tests. If the statistical tests indicated that a particular month had little or no demonstrable effect on yield, it was deleted from further tests.

Data used in this study are from Turkish sources and from the Food and Agriculture Organization of the United Nations (FAO); the World Meterological Organization (WMO); and the Organization for Economic Cooperation and

Development (OECD). Production statistics are all from publications of the Turkish Government. Appendix B contains a test of the final variables against production data furnished by the Agricultural Attache in Turkey.

Turkish Agricultural Production

Before the model and the methodology used in its design are presented, selected aspects of Turkish agricultural production are discussed.

Agricultural Regions

Turkey can be divided into four major agricultural regions: (1) The central section of the country--Antolia--which is a high plateau; (2) the southeastern section--another plateau, which extends into Syria; (3) the northeastern section--which is mainly rugged mountain ranges; and (4) the coastal lowlands--which surround the country on three sides.

Conditions for crop growth in Anatolia are marginal. Rainfall varies from 30 to 40 centimeters, with most of the precipitation falling during September-June (fig. 1). Normally, May has the greatest amount of precipitation. Precipitation during April, May, and June--the critical months

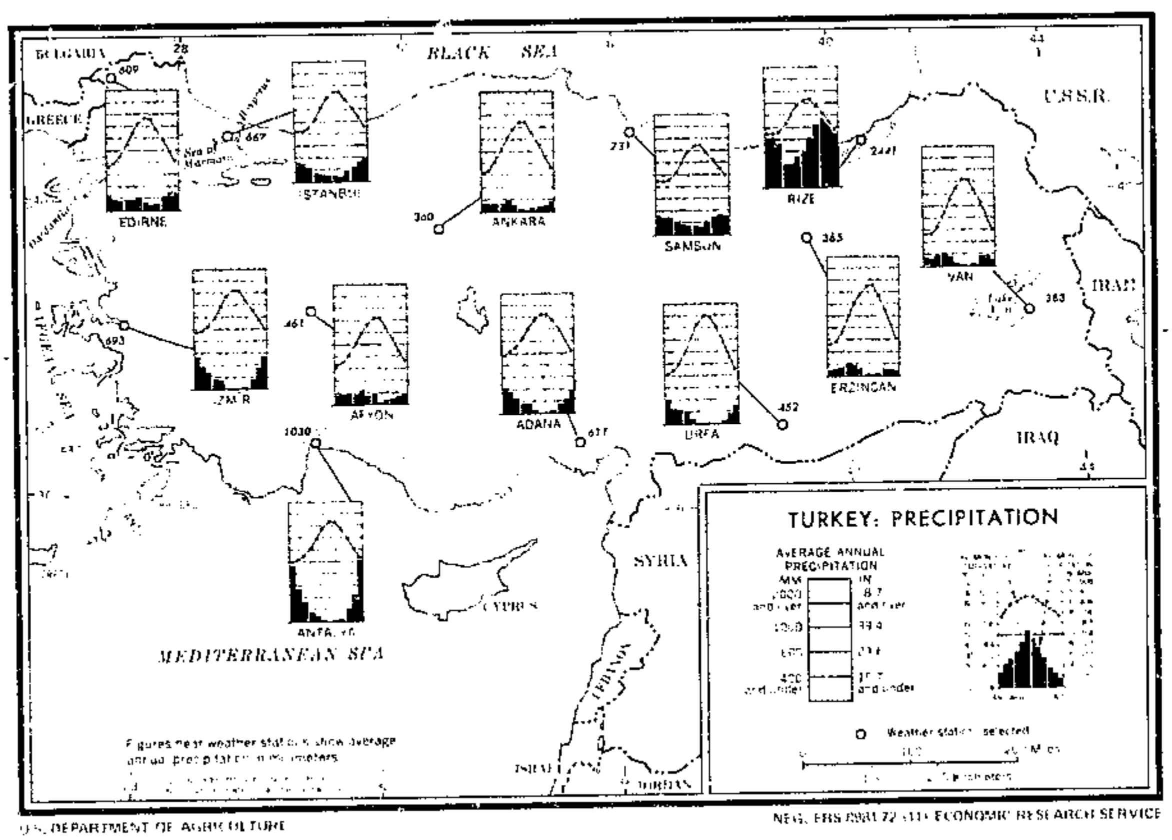

Figure 1

for wheat--averages 3.4, 5.0, and 3.1 centimeters, respectively, at Ankara. Konya, the other major city in the area, has a slightly lower level of annual precipitation. In addition to overall low levels of rainfall, year-to-year variations are high, especially during critical crop production months. For example, during 1948-68, May precipitation at Ankara varied from a low of 1 centimeter in 1949 to a high of 12.2 centimeters in 1963. The result has been frequent drought damage to crops.

The southeastern section of Turkey has somewhat more favorable precipitation levels. However, the distribution is not as good because the highest levels occur during the winter months. Urfu has an average precipitation of 46.1 centimeters, with December, January, and February accounting for nearly 60 percent of the total. The southeastern area tends to have milder winters than does Central Anatolia.

The mountainous northeastern section of Turkey has long winters and short summers. Although wheat is grown here, the area is more suitable for livestock production than for crops.

The coastal sections have generally better precipitation levels, less severe winters, and--in most places--better soil than do the other sections. Here, industrial crops such as tobacco and cotton compete with food crops. High-yielding varieties of Mexican wheat are best adapted to these areas.

Soils

As shown by figures 2 and 4, most Turkish wheat production takes place on marginal to poor soils. Lithosols, which cover approximately 80 percent of the land area, generally are unsuitable for crop production because of stoniness, shallowness, and/or steepness. In the central part of the Anatolian Plateau and in southeastern Turkey, brown and reddish-brown soils predominate. These soils tend to be fine textured but shallow and usually occur on a gently rolling topography. They tend to be low in organic matter and available phosphorous.

The most important arable soils in Turkey are the alluvial soils, which account for most of the area in industrial crops. Alluvial soils are generally moderately fine textured and well drained. Except for a few small sandy or salty areas, most of the alluvial soils in Turkey are well suited for cultivation and irrigation for a wide range of crops. The new high-yielding varieties of wheat are generally grown in alluvial soils.

A third soil group found in the European section of Turkey are grumusols and noncalcic brown soils. Both types tend to be low in organic matter. The grumusols are heavy, poorly drained soils, while the brown soils are well drained. Both soil types require generous applications of nitrogen and phosphorous fertilizers.

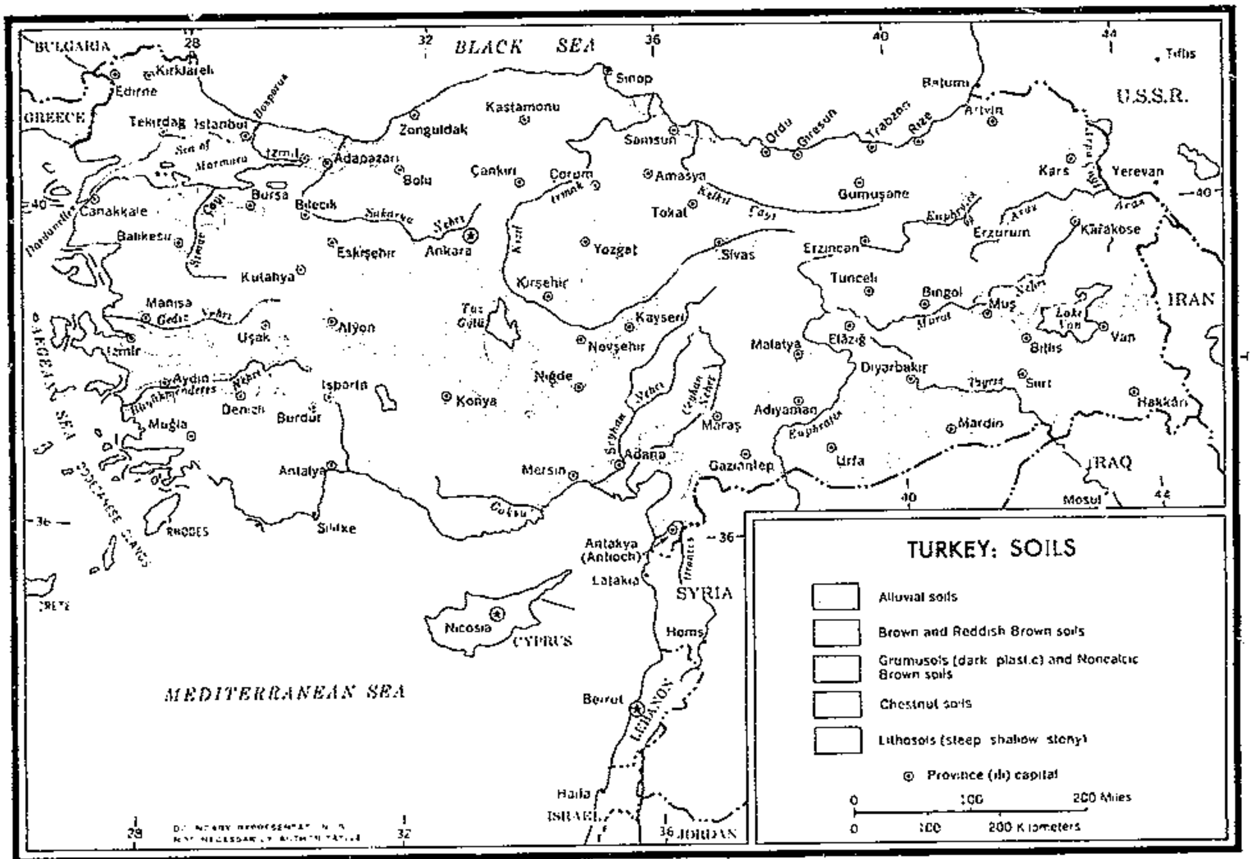

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Figure 2

Land Use

Turkish agriculture is based on roughly 50 million hectares, of which approximately half are cultivated and the remainder are in some form of permanent pasture. In normal years, approximately two-thirds of the cultivated area is sown to crops. The remaining third is in fallow. In 1967, the area cropped was 15.5 million hectares and the area fallowed was 8.3 million hectares. In the same year, 12.5 million hectares were considered to be forest land and 13 million hectares were considered waste land, a category which includes lakes and marshes.

In terms of area planted, cereals are the most important category, and wheat is the most important crop. Barley is the second leading crop. In 1967, industrial crops accounted for 1.7 million hectares and pulses for a half-million hectares. Fruits accounted for a million hectares. Cotton and tobacco--planted on 0.7 million and 0.3 million hectares, respectively--were the leading industrial crops.

Crop production in Turkey is dominated by traditional forms of agriculture. Of an estimated 3.5 million separate agricultural holdings in the country in 1963, approximately 2 million were less than 5 hectares in area. Slightly more than 750,000 of the holdings were under 1 hectare. Many of the smaller farms are classified as subsistent.

To compound the problem of small holdings, inheritance laws have led to considerable fragmentation. OECD indicates that although no up-to-date information is available, the situation is still similar to that in 1950, when only 5 percent of all farm families had a farm in one piece and when the average holding contained seven plots. The only place where the situation has improved is in newly developed irrigation areas, where land consolidation has been mandatory (12). 1/

Estimates from the Turkish State Institute of Statistics (SIS) indicate that in 1967, the country had a total of 75,000 tractors with the potential of cultivating 25 percent of the cropland (23). Results of the 1968 Turkish census of agriculture (land distribution by size of holdings) imply that there were only enough tractors to cultivate the area in holdings of 20 hectares and more. These holdings represented one-fourth of the cropland but only 110,000 of the 3.5 million holdings (25).

Turkish Wheat Production

Wheat is grown in every Province of Turkey, with the Provinces of Central Anatolia accounting for 57 percent of total 1967 production. The area defined as Central Anatolia consists of agricultural regions 1, 8, and 9 (fig. 3). Regions 1 and 9 accounted for nearly half of 1967 wheat production, contributing roughly 2.5 million tons each (fig. 4). Region 8 contributed about 750,000 tons.

1/ Underscored numbers in parentheses refer to references listed at the end of this report.

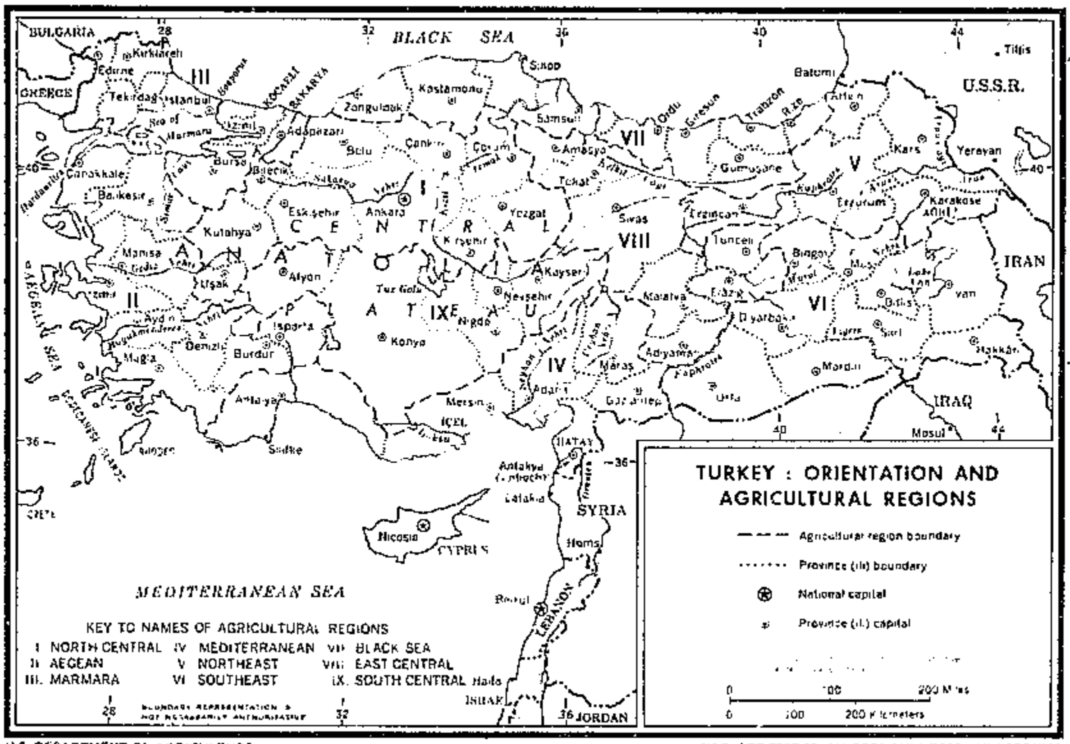

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Figure 3

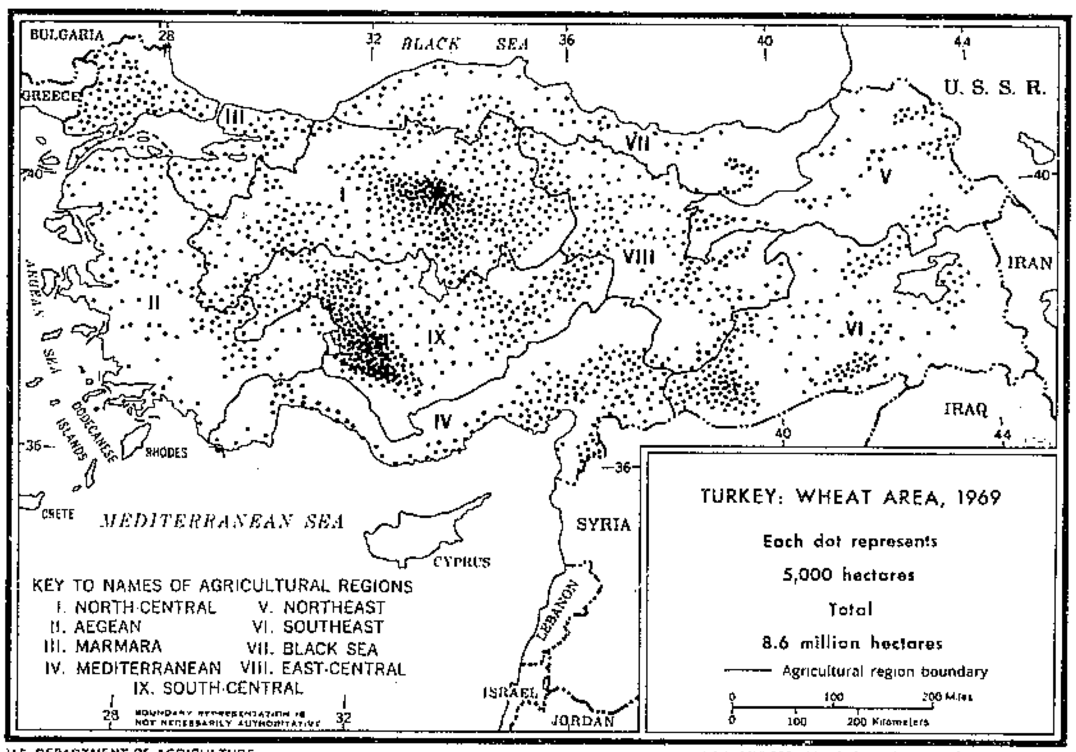

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Figure 4

Regional Variations

Although precipitation in Central Anatolia tends to be near the lower margin necessary for successful wheat production, yields there tend to be at the same level as the national average. During 1949-69, the area planted to wheat doubled and though Central Anatolia maintained its relative share (56 to 57 percent), growth of the three regions differed. Regions 1 and 8 grew more slowly than the national average while region 9 grew at a faster rate.

In many parts of the coastal lowlands (regions 2, 3, 4, and 7), high-value industrial and other crops compete with wheat. It is in these regions, however, that the new high-yielding wheat varieties have been the most successful--probably because the soil and climatic conditions are better than in Central Anatolia. During 1949-69, the coastal regions' share of total area planted to wheat remained at about one-fourth, which indicates that the growth rate of area planted to wheat in the coastal region has been about the same as the national growth rate.

The southeastern section of Turkey--region 6--has a moister climate than does Central Anatolia; however, regional wheat yields tend to be lower than the national average, probably because distribution of rainfall is less favorable. In 1968, the region accounted for approximately 12 percent of Turkey's wheat area. This is an increase from 7.7 percent in 1949, making the region the fastest growing one in Turkey.

Wheat production in the mountainous northeastern section--region 5--is limited by climatic conditions and topography. Consequently, agriculture centers on livestock production. The region accounts for approximately 5 percent of the wheat area and little change in that percentage took place during 1949-68. Wheat yields in region 6 tend to be lower than the national average.

Cultural Practices

Because wheat is grown throughout Turkey and the competing crops vary from area to area, no general crop rotation pattern can be specified. Crop statistics for the individual regions indicate that a wheat-wheat rotation may be common since in some regions more than half the area planted is in wheat. But because fallow statistics are not given for the separate regions, it may be that a wheat-fallow rotation rather than a wheat-wheat rotation is used. For the country as a whole, the area fallowed surpasses the area in wheat, which indicates that a wheat-fallow rotation probably is very common. A second rotation which the area data indicate may be common is a wheat-barley-fallow rotation. In region 1, for example, the 1968 barley area was larger than the area devoted to other nonwheat cereals. Fallowing, principally a moisture-conserving device, is rather inefficient as practiced in Turkey because of the lack of power necessary to perform timely weed control operations (33).

In most of the wheat producing regions, the relative level of technology is quite low and mechanization is very limited. Wooden plows still outnumber those made of steel. Tractor numbers are low relative to cultivated area. The shortage of grain drills--there were only 45,000 in 1967--means that most cereals are broadcast. Also in 1967, there were only 8,000 grain combines and just over 6,000 threshing machines, compared with 2.2 million threshing sleds, which indicates that much of the threshing was being done by the rather primitive threshing sled.

Progress in agricultural technology has occurred, however, in the use of high-yielding wheat varieties. The Mexican-type wheat was first introduced in Turkey in 1965, when 40 kilograms--less than the normal seeding rate for 1 hectare--were imported. By 1970, over 600,000 hectares were being planted to high-yielding varieties. Technological advances have been greater than the growth in area indicates because use of high-yielding varieties involves more than just planting an improved seed variety. It also involves improved cultural practices, especially improved seedbed preparation, sufficient inputs of fertilizer, more adequate control of the water supply, irrigation if possible, and use of pesticides.

National Agricultural Policy

The Turkish economy is guided by national 5-year plans. The first plan, covering 1963-67, called for a 7-percent growth rate in gross national product (GNP), but allowed the various sectors of the economy to have different growth rates. Emphasis was given to industrial development. In the agricultural sector, output was expected to increase by 4.2 percent. Turkish planners believed that this rate was feasible for agriculture to meet, and that in meeting it, agriculture would not be a drag on the rest of the economy. OECD estimates that during 1963-67, agricultural output in Turkey grew only 3 percent (12).

In the 1968-72 plan, emphasis was again on industrial development, GNP was again expected to grow by 7 percent, and agriculture by 4.2 percent. If the targets set in the 1968-72 plan have been met, agricultural output as a percentage of GNP will have declined from 30 percent in 1967 to 25 percent in 1972. The planned 4.2-percent growth rate for agriculture was dependent on an increase in cereal production. The 1968-72 plan called for a leveling off in wheat area and an increase in area of other cereals. Wheat yields were to have risen approximately 3 percent annually. If wheat area has been kept at a stable level as planned, production will have increased at the same rate as yield, which means that nonwheat crops will have increased by more than 4.2 percent annually.

The plan to increase total cereal area is in conflict with the advice of most agricultural experts, who recommend that land in Turkey be diverted from cereal production to permanent pasture because soil fertility is low and much of the land is subject to serious erosion. These experts indicate that some increase in cropped area could occur simply by more efficient fallowing practices that would permit cropping a larger proportion of the land (12).

Another aspect of Turkish agricultural policy is their price policy. The main agency responsible for wheat pricing is the Soils Products Office (Toprok Mahsuelleri Ofisi or TMO), a state enterprise formed in 1938. TMO operates grain storage and receiving facilities and currently has storage room for approximately 20 percent of the wheat production. TMO's function is to support wheat prices and to ensure orderly marketing between producer and consumer.

Operation of TMO is not fully advantageous to producers in that the guaranteed price is announced just before harvest. There are neither minimum nor maximum delivery quotas. The TMO selling price, really the wholesale price, is 6 to 9 Kurus per kilo above the purchase price. In years of short supply, TMO uses rationing procedures to control distribution. In addition, TMO is the only agency authorized to import wheat. The farm price or village market price is usually above the TMO purchase price because commercial purchasers must pay slightly more than TMO prices to fill their short-run needs. Because TMO provides storage facilities, millers and other commercial wheat users are relieved of the necessity of providing storage for their long-run needs. TMO provides price-support activities for other cereals as well as wheat, but it is not nearly as active in these markets as it is in the wheat market (7).

Wheat Consumption

Turkey has one of the highest levels of per capita wheat consumption in the world. FAO statistics, based on Turkish production data, indicate that annual per capita consumption of all cereals was 173 kilograms (kg.) in 1968 (6, p. 434). A 1969 OECD study estimated that per capita consumption of all cereals was 200 kg., of which 163 kg. was wheat (12, pp. 308-309). The FAO and OECD estimates were constructed from supply-distribution tables that treat consumption as a residual.

A Roberts College (Istanbul, Turkey) study, which was based on consumption surveys, estimated per capita wheat consumption at 180 kg. (15). The study showed very little difference between rural and urban levels of consumption. A secondary data source--a study by Gunes--is cited in which per capita wheat consumption is estimated to be 213 kg. for rural areas and 164 kg. for urban areas. The average for the country would be 198 kg. The Roberts College study shows a gradual increase in per capita wheat consumption during 1948-65. OECD suggests the increase may have come at the expense of other food cereals such as corn.

These vastly differing estimates of cereal and wheat consumption stem from two problems. First, the consumption estimates often are based on production estimates that appear to most analysts to be too high (11, 15, 33). Second, most of the Turkish wheat crop is consumed by the production unit and knowledge about what the individual farmer does with his wheat crop is very limited. Depending on the size of his crop, a farmer may add or subtract from his personal storage. He may increase or decrease his family's level of consumption or he may buy or sell in the village market.

In many areas of Turkey, marketing outside the village is difficult because of limited transportation facilities. In addition, the marketing system is not well organized and, except for the support price, price information is not readily available to the small farmer. Wheat that does move past the village level is usually bought by the middleman who delivers it to a central market. The second 5-year plan encourages farmers to set up cooperatives to increase the efficiency of the marketing system.

Wheat Trade

In any one year, Turkey may be either an importer or an exporter of wheat. FAO data show that during 1948-70, Turkey's wheat trade ranged from over 950,000 tons in exports to over 850,000 tons in imports (table 1). 2/ Most imports are supplied by the United States under PL 480 agreements. A significant fact is that Turkey has moved from being a net exporter in the 1950's to being a net importer. Due to the large 1971 crop resulting from favorable weather, Turkey exported some wheat during the 1971/72 marketing year but may still be a net importer in coming years.

Because wheat production has increased more rapidly than population, it would appear that rather than becoming an importer, Turkey should have strengthened its export position. However, according to the Roberts College study, per capita wheat consumption rose from 135 to 180 kg. during 1948-65 (15). That increase coupled with the increase in population means that total consumption rose from 2.78 million to 6.06 million tons over the same period, an increase of 118 percent. However, consumption of corn--the second most important food cereal--showed only a 30-percent increase. Thus, it appears that much of the increase in per capita wheat consumption has come about because wheat has been substituted for other cereals. As a consequence, the wheat export position of Turkey has not improved significantly.

FORECASTING METHODOLOGY

To quantitatively identify the relationship between wheat production and weather in Turkey, two basic classes of variables were used: (1) Input and output variables for wheat production and (2) weather variables. These variables were used in models to estimate wheat yield, area planted, and, finally, production.

Wheat Production--Output Variables

In general, wheat production includes three separate components: planted acreage, yield, and production itself. Wheat yields in Turkey are estimated from samples taken by officials of the Ministry of Agriculture.

2/ All tonnages are metric.

Table 1--Estimates of wheat production, trade, and domestic supply, Turkey, 1948-70

Year	Production 1/	Imports		Exports (FAO) 4/	Net trade 5/	Domestic supply 6/
		FAO 2/	PL 480 3/			
	1,000 metric tons					
1948	4,867	9.3	--	--	9.3	4,876
1949	2,517	170.8	--	--	170.8	2,688
1950	3,872	214.7	--	--	214.7	4,087
1951	5,600	107.3	--	20.3	87.0	5,687
1952	6,447	0.8	--	462.3	-461.5	5,985
1953	8,000	--	--	600.6	-600.6	7,399
1954	4,900	0.7	29.2	953.5	-952.8	3,947
1955	6,900	222.6	247.6	159.9	62.7	6,963
1956	6,400	185.4	235.8	176.9	8.5	6,409
1957	8,300	444.5	704.2	--	444.5	8,745
1958	8,550	59.7	254.4	33.6	26.1	8,576
1959	7,852	--	--	377.3	-377.3	7,475
1960	8,450	98.9	389.4	35.3	63.6	8,514
1961	7,000	856.1	952.9	1.3	854.8	7,855
1962	8,450	689.6	1,031.3	--	689.6	9,140
1963	10,000	786.8	489.2	--	786.8	10,787
1964	8,300	80.8	123.3	--	80.8	8,381
1965	8,500	348.5	331.8	--	348.5	8,848
1966	9,600	298.8	298.4	--	298.8	9,899
1967	10,000	14.2	13.0	--	14.2	10,014
1968	9,520	16.9	26.9	1.6	14.3	9,534
1969	10,500	220.7	414.7	--	220.7	10,721
1970	10,593	897.0	7/	--	897.0	11,490

-- Means no reported trade.

1/ Source: (23).
2/ Imports as reported by the Food and Agriculture Organization of the United Nations (FAO) (5).
3/ P.L. 480 imports as reported by the Turkish State Institute of Statistics (SIS) to the U.S. Agency for International Development (27).
4/ Exports as reported by FAO (5).
5/ Imports minus exports (FAO statistics).
6/ Production plus net trade. These figures do not include stock changes, which would also affect supply.
7/ The level for 1970 has not been published.

The samples, which are 1 meter square, are taken at random roadside locations in the wheat producing areas. Wheat area is estimated by the Provincial agricultural agent, whose job is somewhat comparable to that of a county extension agent in the United States. Production estimates are the product of estimated yield and estimated area. 3/

Yield

In Turkey, the main available technique to raise wheat yields is application of larger quantities of fertilizer. There are no available statistics showing either the quantity of fertilizer applied per hectare of wheat or the proportion of total fertilizer that is applied on wheat. While application of fertilizer is fairly certain to result in increased yields, there usually is not enough fertilizer available to meet potential demand (10).

Use of better seed varieties will also usually provide increased wheat yields. However, available information indicates that in Turkey, little use of new varieties took place during 1948-68, the years covered in this analysis. Since 1968, adoption of improved varieties (primarily Mexican wheat) has significantly improved yields in some areas and to a lesser extent, has had important effects on the national yield. 4/

Mechanization, another means of increasing yields, is not fully under the individual farmer's control. Mechanization allows better timing and more effective tillage operations. This means less moisture loss, better weed control, better seed placement, and less loss at harvest. The rate of mechanization is slow in Turkish agriculture, because the small size of most farms limits both the efficiency of new machinery and the ability of the individual farmer to pay for the machinery.

A fourth and obvious factor that affects yields is weather. Quentin West, in a study on agricultural development in Turkey, indicated that spring rainfall is a primary factor in the determination of wheat yields (33). Because a significant proportion of the wheat crop is fall planted and is still sown by broadcasting, fall rainfall is important to the extent that it ensures adequate seedbed preparation and germination. While a dry fall may mean poor germination, too much fall precipitation can mean delayed planting. Both extremes can have a deleterious influence on fall growth, which is the basis for the following spring growth. The work by West indicated that in general, fall rainfall has a positive influence on yields, though not as strong as that of spring rainfall.

3/ Yield, acreage, and production data used in this analysis are from the Turkish State Institute of Statistics (SIS). The American Agricultural Attache in Turkey provides production data that are considerably smaller than the SIS data. SIS data were used, however, because unlike the American data, they are available on a national, regional, and Provincial basis.

4/ For a discussion of the use of high-yielding varieties in developing countries and results obtained from them, see (21).

Increases in irrigated area in Turkey have probably had only a little influence on increasing national wheat yields because only a few of the new irrigation projects have been for wheat production. The first 5-year plan estimated that 200,000 hectares of wheat were irrigated in 1963. The second plan calls for irrigated wheat area to increase to 265,000 hectares by the end of 1972. Both plans have called for most new irrigated land to be used in the production of noncereal crops. Even for cereal area, irrigated acreage of rice and corn is expected to increase faster than irrigated wheat acreage (13).

During 1946-70, regional and national wheat yields in Turkey varied a great deal (table 2). National yields varied from a low of 628 kg. in 1949 to a high of 1,273 kg. in 1963--the range, 645 kg., was slightly more than half as large as recent yields. On a regional basis, the smallest range was 589 kg. in region 7 and the largest range was 1,061 kg. in region 9.

Area Planted

Area planted, without doubt, is the best measure of planned production at the farm level. For example, if a Turkish farmer wishes to increase his wheat production from 4 to 8 tons, he probably will double the area he plants rather than apply more fertilizer or pesticides. The same phenomenon appears to have taken place in the national economy in the early 1950's, when the Turkish Government encouraged plowing pastureland to increase wheat production.

In addition to the price supports for wheat, the market system for the commodity is relatively free. Hence, it is logical to assume that year-to-year changes in wheat area are influenced by price relationships between wheat and alternative commodities--barley, for example. Attempting to define the relevant price in terms of just one ratio involves a certain danger because regional differences in production patterns probably mean that different ratios are used by farmers to guide production planning. For instance, a farmer in eastern Turkey may base his decision on the relative prices of wheat and livestock, while for the farmer in the Curkova Delta, the relevant ratio may involve wheat and cotton.

During 1946-68, total cropped area and cereal area in Turkey nearly doubled (table 3). However, the separate components of cereal area did not follow that pattern. Wheat area more than doubled, but for barley and other cereal crops, area planted did not increase as fast as total cereals. Despite large increases in total area cropped, cereals maintained very nearly the same proportion of total cropped area throughout the period. Wheat as a percentage of total cereal showed a fairly steady increase. The proportion of cereals planted on fallow land ranged from 47 percent in 1952 to 66 percent in 1964. A 63 to 65 percentage range would include most of the years.

Table 2--National and regional wheat yields, Turkey, 1946-70

Year 1/	Turkey	Central Anatolia 2/	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8	Region 9
	Kilograms per hectare										
1946	952	961	1,028	798	1,110	934	909	743	875	833	977
1947	777	801	726	649	844	558	850	848	796	729	961
1948	1,086	1,192	1,201	1,066	1,086	913	639	995	788	899	1,376
1949	628	552	722	867	956	892	473	498	677	442	387
1950	864	809	656	868	778	1,213	1,311	965	690	875	708
1951	1,169	1,164	1,179	1,107	1,177	1,050	1,259	1,333	1,088	1,274	1,077
1952	1,194	1,173	1,185	1,118	1,112	1,357	1,359	1,312	1,082	1,188	1,147
1953	1,248	1,371	1,425	1,557	1,121	1,227	1,219	869	1,016	1,261	1,342
1954	765	676	705	1,113	900	986	905	660	818	635	658
1955	977	963	954	1,217	1,184	1,063	740	868	865	1,026	947
1956	872	774	807	1,220	791	1,133	863	971	1,060	715	762
1957	1,159	1,136	1,141	1,274	1,260	1,409	1,118	1,019	1,085	1,091	1,151
1958	1,147	1,162	1,152	1,398	1,066	1,188	1,191	902	1,139	1,182	1,195
1959	1,042	1,038	1,167	1,226	1,249	1,202	934	763	996	1,050	880
1960	1,097	1,100	1,109	1,265	1,181	1,338	945	791	1,093	947	1,156
1961	907	829	892	1,135	1,085	1,306	462	946	974	836	751
1962	1,083	974	1,033	1,266	1,216	1,414	1,114	1,202	999	987	904
1963	1,273	1,342	1,329	1,230	1,009	1,259	1,053	1,258	1,150	1,184	1,428
1964	1,054	1,050	1,081	1,188	1,256	1,285	1,003	628	1,195	1,251	932
1965	1,075	1,057	1,079	1,212	1,386	1,200	946	836	1,115	982	1,068
1966	1,208	1,224	1,298	1,272	1,329	1,260	1,007	1,104	1,122	1,177	1,168
1967	1,250	1,262	1,272	1,319	1,433	1,382	1,142	942	1,266	1,042	1,344
1968	1,154	1,172	1,154	1,441	1,151	1,401	742	905	1,070	983	1,272
1969	1,230	1,182	1,176	1,635	1,335	1,729	781	848	1,148	1,003	1,308
1970	1,229	--	--	--	--	--	--	--	--	--	--

-- Means regional data have not been published.

1/ Year of harvest for crops planted in the fall.
2/ Central Anatolia consists of regions 1, 8, and 9.

Source: (23, 26).

Table 3--Area planted to all crops, cereals, wheat, barley, and other cereals, and area fallowed, Turkey, 1946-70

Year 1/	Area planted					Fallow	Cereals as a percentage of all crops	Wheat as a percentage of cereals	Cereals on fallow 3/
	All crops 2/	Cereals	Wheat	Barley	Other cereals				
	1,000 hectares						Percent		
1946	13,093	7,193	3,831	1,736	1,626	4,680	54.9	53.3	64.2
1947	13,575	7,631	4,177	1,805	1,649	4,673	56.2	54.7	61.3
1948	13,900	8,071	4,538	1,828	1,705	4,423	58.1	56.2	57.9
1949	13,264	7,525	4,008	1,759	1,758	4,274	56.7	53.3	58.8
1950	14,542	8,244	4,477	1,902	1,865	4,674	56.7	54.3	51.8
1951	15,272	8,804	4,790	2,059	1,955	4,672	57.6	54.4	53.1
1952	17,361	9,868	5,400	2,312	2,156	5,586	56.8	54.7	47.3
1953	18,812	11,077	6,410	2,437	2,230	5,791	58.9	57.9	50.4
1954	19,616	11,271	6,405	2,500	2,366	6,408	57.5	56.8	51.4
1955	20,998	12,079	7,060	2,640	2,379	6,793	57.5	58.4	53.1
1956	22,453	12,370	7,335	2,612	2,423	7,897	55.1	59.3	54.9
1957	22,161	12,207	7,157	2,630	2,420	7,769	55.1	58.6	64.7
1958	22,765	12,547	7,450	2,700	2,397	8,001	55.1	59.3	61.9
1959	22,940	12,687	7,535	2,750	2,402	7,920	55.3	59.4	63.1
1960	23,264	12,945	7,700	2,836	2,409	7,959	55.6	59.5	61.2
1961	23,076	12,865	7,717	2,786	2,362	7,948	55.8	60.0	61.9
1962	23,215	12,965	7,800	2,800	2,365	8,048	55.8	60.2	61.3
1963	23,823	13,017	7,850	2,850	2,317	8,547	54.6	60.3	61.8
1964	23,843	12,930	7,870	2,750	2,310	8,476	54.2	60.9	66.1
1965	23,841	12,960	7,900	2,770	2,290	8,547	54.4	61.0	65.4
1966	23,982	12,974	7,950	2,710	2,314	8,528	54.1	61.3	65.9
1967	23,836	13,014	8,000	2,725	2,289	8,323	54.5	61.5	65.4
1968	24,092	13,132	8,250	2,730	2,152	8,192	54.5	62.8	63.4
1969	24,672	13,475	8,660	2,687	2,128	8,824	54.6	64.3	64.5
1970	24,294	13,240	8,616	2,590	2,034	8,705	54.5	65.1	66.6

1/ Year of harvest for crops planted in the fall.
2/ Includes fallow.
3/ The previous year's fallow area as a percentage of cereal area in the current year.

Source: (23, 26).

Growth in the proportion of total area planted to wheat during 1946-70 was uneven on a regional basis (table 4). For central Anatolia as a whole (regions 1, 8, and 9), the proportion declined slightly. In region 9, however, the increase in wheat area was greater than the national average increase. In region 6--the southeastern plateau--area planted to wheat also increased faster than the national increase.

Production

Wheat production, as estimated by Turkish officials, is estimated area multiplied by estimated yield. Table 5 shows that production also exhibited a great deal of year-to-year variation during 1946-70. Average production was 7,280,000 tons. The range in production was 3.1 million tons, varying from 2.5 million tons in 1949 to 10.6 million tons in 1970. However, the range of production fluctuations is not as meaningful as the range in yield fluctuations because a second factor, area planted, is involved. Techniques for separating the relative effects of the two components are discussed in Sachrin (18) and in Burt and Fenley (2).

Wheat Production--Input Variables

In addition to the output variables discussed above, 1948-68 series were developed for selected classes of agricultural input variables. These series included mechanization, fertilizer use, prices, and weather. Data for the first three series are presented in appendix tables D-1, D-2, and D-3. Weather data, consisting of monthly precipitation and monthly average temperature, were gathered from 13 weather stations scattered throughout Turkey. In choosing the stations, an attempt was made to use cities that are important centers of wheat production and whose weather conditions represent typical climatic conditions in the area.

The monthly weather data were converted into an aridity index that was developed by De Martoneau, a French climatologist. Equation (A) was used to make the conversion. Equation (B) was used to convert the monthly index to 2- and 3-month cumulative indexes:

(A) $I_i = (12\ P_i) \ /\ (T_i + 10)$

(B) $I_j = \Sigma I_i\ V_i\ /U$

Where:

I_i = monthly aridity index.

P_i = monthly precipitation.

T_i = monthly average temperature.

I_j = cumulative aridity index.

V_i = statistical variance of I_i.

V = the sum of the V_i.

Table 4--Total area planted to wheat, and regional acreage as a percentage of total, Turkey, 1946-70

Year 1/	Total	Central Anatolia 2/	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8	Region 9
	1,000 hectares	Percent									
1946	3,831	58.6	25.2	9.6	7.3	7.1	4.9	6.3	6.2	14.6	18.8
1947	4,177	58.1	26.4	9.9	6.9	7.2	5.7	6.5	5.7	13.4	18.3
1948	4,538	56.4	26.8	8.7	8.2	6.9	5.0	8.2	5.3	11.9	17.7
1949	4,008	57.2	26.1	8.8	7.7	8.0	5.0	7.7	5.6	12.6	18.5
1950	4,477	58.5	27.4	9.5	8.1	6.7	4.3	7.1	5.8	11.3	19.8
1951	4,790	56.2	27.3	8.6	8.7	6.7	5.2	9.1	5.5	10.7	18.2
1952	5,400	58.5	28.3	7.6	7.7	6.9	5.0	9.1	5.2	10.7	19.5
1953	6,410	57.8	29.5	6.8	7.0	6.9	5.7	10.9	4.9	9.6	18.7
1954	6,405	56.1	26.2	7.1	6.9	8.1	5.7	11.7	4.4	9.1	20.8
1955	7,060	58.4	26.9	6.8	6.8	7.4	5.6	10.5	4.5	9.4	22.1
1956	7,335	58.7	25.8	6.6	5.8	7.5	5.5	11.6	4.3	10.1	22.8
1957	7,157	59.0	25.9	6.8	6.5	7.8	5.3	10.1	4.4	10.5	22.6
1958	7,450	58.4	25.4	7.0	6.7	8.1	4.8	10.4	4.5	10.0	23.0
1959	7,535	58.5	25.7	6.9	6.6	7.9	4.7	10.5	4.9	9.8	23.0
1960	7,700	58.9	24.9	6.9	6.6	8.1	4.6	10.1	4.8	10.7	23.3
1961	7,717	58.0	25.3	6.9	6.6	8.1	4.8	10.7	4.9	9.7	23.0
1962	7,800	56.8	24.8	6.9	6.9	8.7	4.5	11.4	4.8	9.3	22.7
1963	7,850	57.6	24.5	6.8	6.7	8.4	4.4	11.0	5.1	10.1	23.0
1964	7,870	57.6	24.4	6.9	6.9	8.7	4.5	10.5	4.9	9.9	23.3
1965	7,900	56.9	23.9	7.2	6.9	8.7	4.4	11.3	4.6	10.3	22.7
1966	7,950	57.3	23.9	7.0	5.7	9.0	4.7	11.3	5.0	9.9	23.5
1967	8,000	56.7	24.1	6.7	7.1	8.9	4.3	11.6	4.7	9.7	22.9
1968	8,250	55.9	23.8	7.0	7.0	9.0	4.7	11.5	4.9	9.7	22.4
1969	8,660	55.5	23.9	7.1	6.9	9.4	4.6	11.4	5.1	9.5	22.1
1970	8,616	--	--	--	--	--	--	--	--	--	--

-- Means regional data have not been published.

1/ Year of harvest for crops planted in the fall.
2/ Central Anatolia consists of regions 1, 8, and 9.

Source: (23, 26).

Table 5--Estimates of national and regional wheat production, Turkey, 1946-70

Year 1/	Turkey	Central Anatolia 2/	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8	Region 9
	1,000 metric tons										
1946	3,648	2,157	991	292	312	255	190	217	225	465	701
1947	3,246	1,943	800	268	243	168	204	229	191	407	736
1948	4,867	3,053	1,461	420	405	285	145	369	190	487	1,105
1949	2,517	1,265	755	307	294	249	95	154	153	223	287
1950	3,872	2,120	1,050	368	280	364	253	307	180	441	629
1951	5,600	3,134	1,540	455	492	337	316	581	283	655	939
1952	6,447	3,706	1,812	456	465	506	367	644	303	689	1,205
1953	8,000	5,079	2,695	508	501	540	446	609	317	772	1,612
1954	4,900	2,429	1,181	504	397	512	333	496	229	371	877
1955	6,900	3,974	1,813	588	566	557	293	646	276	682	1,479
1956	6,400	3,329	1,530	587	339	622	347	840	336	528	1,271
1957	8,300	4,797	2,114	618	586	788	427	740	344	817	1,866
1958	8,550	5,058	2,129	731	534	716	428	698	385	886	2,043
1959	7,852	4,572	2,263	639	621	714	336	602	368	773	1,536
1960	8,450	4,993	2,209	675	597	831	338	616	400	734	2,050
1961	7,000	3,705	1,740	605	555	818	171	778	368	630	1,335
1962	8,450	4,313	1,998	682	653	961	394	1,074	373	719	1,596
1963	10,000	6,076	2,553	657	530	832	364	1,085	456	947	2,576
1964	8,300	4,763	2,080	645	684	881	354	521	452	977	1,706
1965	8,500	4,752	2,038	685	759	820	331	748	405	801	1,913
1966	9,600	5,576	2,470	705	598	901	374	994	452	927	2,179
1967	10,000	5,719	2,450	737	811	988	388	871	486	811	2,458
1968	9,520	5,405	2,266	832	669	1,038	288	859	429	785	2,354
1969	10,500	5,686	2,428	1,002	785	1,409	295	813	510	793	2,465
1970	10,593	--	--	--	--	--	--	--	--	--	--

-- Means regional data have not been published.

1/ Year of harvest for crops planted in the fall.
2/ Central Anatolia consists of regions 1, 8, and 9.

Source: (23, 26).

Equation (A) indicates that the index varies directly with precipitation and inversely with temperature. Appendix A contains sample calculations of the index. Preliminary regressions made to compare use of the monthly indexes with use of monthly precipitation data indicated a small advantage of using the indexes. Consequently, they were used in the analysis.

Results of Regression Runs

To explain variations in wheat yields, area planted, and production during 1948-68, three separate sets of regression runs were made, with each drawing from the data sets described in the preceding sections. The objective of each set of runs was to develop a model that would provide a forecast of future production or of some component of production. Using this methodology assumes that a model that explains past variations will have the capability of forecasting future variation.

Yield Model

The yield model tested variables representing weather, mechanization, and fertilizer use. Data on year-to-year changes in irrigated area were not available and area planted to new wheat varieties was too small to affect national yields. Consequently, these two variables were not tested. The basic testing pattern was to first make a regression run with weather data for the full 12 months of a crop year (Sept.-Aug.) Only data for those months that appeared to significantly affect yields were kept in the model. Weather data for these months were used in tests against the variables for mechanization and fertilizer use.

A problem that arises is the stage of geographic aggregation at which the calculations should take place. Logically, one would expect that the smaller the prediction unit the better the results, since climatic patterns vary and the data being used are most accurate in the immediate vicinity of the weather station. Table 6, which presents five equations, compares three aggregation levels. Equation 1 represents the smallest level of aggregation--one weather station in one Province. It gives quite a large R^2, which indicates the equation explains a good portion of the original variation. However, the large standard deviation, roughly 17 percent of current yields, is too large to be used for predictive purposes.

Equation 2 gives a second level of aggregation. Weather data from Ankara--in region 1--is tested against region 1 wheat yields (see fig. 3 for the location of region 1). Region 1 produces more wheat than do any of the other eight regions, although region 9 runs a close second. Using the full region rather than a single Province in equation 2 improved the size of the standard deviation but resulted in a smaller R^2.

Equations 3 and 4 are not fully comparable with equations 1, 2, and 5 because they have slightly different variables. Equation 3 regresses region 1 yields on a three-station, weighted-average index. Equation 4 uses a 13-station, weighted-average index to predict national yields. In terms of information, equation 3 uses slightly more information and equation 4 slightly less than the other three equations. These equations are about the same as equation 2 if the standard deviations are compared, but they are slightly inferior in terms of R^2.

In equation 5, Ankara weather data are tested against national wheat yields. This was the best equation as measured by both R^2 and the standard deviation because national yield fluctuates less than do regional yields. Consequently, forecasts based on a set of weather data closely associated with yields in a major component of the total (as equation 5 indicates) result in a smaller standard deviation than do forecasts based on weather and yield data from much smaller components (regions).

Table 6--Selected equations comparing 1948-68 weather data and wheat yields, three aggregation levels, Turkey

Equation and level of aggregation	Inter-cept	Coefficients					R^2	SDY 1/
		Oct.-Nov.	Jan.-Feb.	May	June	Trend		
(1) Ankara weather and Ankara yields	538	0.9	-1.5	12.3	0.0	20.5	.68	172
(2) Ankara weather and region 1 yields	791	2.4	-1.7	9.1	1.3	9.4	.62	137
(3) Region 1 weather (3 stations) and region 1 yields	373	2/2.3	3/-1.7	4/7.9	--	5/ .33	.55	148
(4) National weather (13 stations) and national yields	638	6/2.2	7/-2.24	8.3	--	5/0.28	.49	140
(5) Ankara weather and national yields	780	1.5	-1.7	7.8	1.3	11.7	.72	107

1/ Standard deviation of the estimate.
2/ Sept., Oct., and Nov. combination.
3/ Dec., Jan., and Feb. combination.
4/ Mar., Apr., and May combination.
5/ Plow numbers.
6/ Nov. only.
7/ Feb. only.

The signs on the coefficients follow the expected pattern. The fall and spring variables have positive coefficients indicating the importance of precipitation during those seasons. The coefficient for the winter months is negative, indicating that temperature which varies inversely with the index has an important influence on yields. The positive coefficient on trend indicates that average yields have been rising.

The major conclusion to be drawn from table 6 is that Ankara weather data provide an estimate of total weather effects on wheat yields that is just as good as any of the subaggregations tested. As a consequence, further tests will concentrate on Ankara weather data and national yields.

Equations 6 and 7 are shown to indicate the results of using either separate variables for May and June--the most important months--or combining data for the 2 months into one variable.

6. $Y = 788.9 + 177X_4 - 1.56X_5 + 7.66X_6 + 10.3X_{11} + 10.88X_7$

$t =$ 0.44 2.06 4.18 0.48 2.73

$R^2 = .83$ SD = 108.0

7. $Y = 747.2 + 2.00X_4 - 1.50X_5 + 10.97X_{12} + 11.05X_7$

$t =$ 0.49 1.94 4.00 2.75

$R^2 = 0.81$ SD = 110.1

Where:

Time = 1948-68.

Y = National yields in kilograms per hectare.

X_4 = Oct.-Nov. aridity index for Ankara.

X_5 = Jan.-Feb. aridity index for Ankara.

X_6 = May aridity index for Ankara.

X_7 = Trend line 1948 = 1.

X_{11} = June aridity index for Ankara.

X_{12} = May-June aridity index for Ankara.

X_{13} = Fertilizer consumed in 1,000 metric tons.

t = t statistic.

R^2 = Coefficient of correlation.

SD = Standard deviation of the estimate.

A comparison of the two equations indicates that keeping May and June weather separate appears to give a slightly better estimating equation (equation 6) as judged by both R^2 and the standard deviation. However, the coefficient on the June variable (X_{11}) is not significant, so under normal circumstances it would be dropped from further testing. Thus, equation 7 was selected for further testing since it includes the June weather information and the coefficient is highly significant.

Equation 8 is a variation on equation 7 in that it indicates what happens if plow numbers (X_{14}) are substituted for the trend line (X_7). Comparing equations 7 and 8 is in effect testing whether steel plow numbers or a simple trend line fit the data better. The comparison here indicates the trend variable has a small advantage, though the difference is very small.

8. $Y = 600.8 + 1.79X_4 - 1.48X_5 + 11.18X_{12} + 0.27X_{14}$

$t =$ 0.44 1.90 4.03 2.66

$R^2 = 0.81$ SD = 111.3

Equation 9 is a second variation on equation 7 in that it includes the fertilizer variable (X_{13}) as a measure of advancing technology. Equation 9 is the better of the three equations, but again the difference is very small. The fall (Oct.-Nov.) weather variable in equations 7, 8, and 9 is not significant at either the 1- or 5-percent levels.

9. $Y = 889.7 - 0.35X_4 - 2.05X_5 + 11.17X_{12} + 0.13X_{13}$

$t =$ 0.09 2.71 4.17 2.95

$R^2 = 0.82$ SD = 107.5

In equation 10, the fall variable was omitted. Equation 10 results in a smaller standard deviation and no change in the R^2. Since equation 10 was the best equation (as judged by SD), it was used to obtain the yield predictions that 1969, 1970, and 1971 data would have indicated. These are presented in table 7 on page 26. Appendix table B-2 contains data on actual, estimated, and residual yields for 1948-68 as estimated by equation 10.

10. $Y = 883.9 - 2.03X_5 + 11.15X_{12} + 0.13X_{13}$

$t =$ 2.93 4.31 3.04

$R^2 = 0.82$ SD = 104.3

Area Model

Since wheat production as calculated by Turkish officials is the product of area and yield, an area model was developed for use with the yield equations to forecast production. It is presented below as equation 11. As the equation indicates, area planted in the previous year is closely related to the amount planted in the current year, with some of the difference probably due to price changes. The t test on the price variable indicates it is significant only at the 25-percent confidence level, usually considered non-significant.

11. $$A = 296.1 + 38.43P + 0.92A_{t-1} - 1.64T$$

$$t = \quad 0.81 \quad 6.64 \quad 0.05$$

$$R^2 = 0.95 \quad SD = 319 \quad Ep = 0.16$$

Where:

A = Area planted to wheat in 1,000 hectare units.

A_{t-1} = Area planted to wheat in the previous year.

P = Wheat price received by farmers deflated by the index of cereal prices and lagged 1 year. The units are Kurus/kilogram taken from table 4.

T = Trend value = 1 - 21 (1948-68).

t = t statistic.

R^2 = Coefficient of determination.

SD = Standard deviation of the estimate.

Ep = Short-run supply elasticity.

Appendix table B-2 contains a series of actual, estimated, and residual wheat area for 1948-68. Table 7 presents similar information for 1969-71.

Production Model

Production can be estimated indirectly by multiplying the yield estimate by the area estimate. A direct estimate can be made if a regression equation is fitted to the production data and that equation is used to estimate production. Logically, such a production equation will contain the same variables, or at least the most significant variables, as the yield and the area equations contain. Equation 12 presented below is obtained from using the most significant variables in the area and yield equations.

12. $$Wp = 216.7 + 0.94A_{t-1} - 12.14X_9 + 78.76X_{12} + 0.89X_{13}$$

$$t = \quad 5.09 \qquad 1.97 \qquad 3.70 \qquad 1.98$$

$$R^2 = 0.93 \qquad SD = 851.0$$

Where:

Wp = Wheat production in 1,000 metric tons.

A_{t-1} = Wheat area in the previous year in 1,000 hectare units.

X_9 = Jan.-Feb. aridity index for Ankara.

X_{12} = May-June aridity index for Ankara.

X_{13} = Fertilizer consumed in 1,000 metric tons.

t = t statistic.

R^2 = Coefficient of determination.

SD = Standard deviation of the estimate.

Time = 1949-68.

Equation 12 contains all the independent variables used in equation 10, the yield equation. From equation 11--the area equation--only the previous year's area proved to be significant. The standard deviation is approximately 9 percent of production in 1968, a year of high but not record production.

Appendix table B-2 contains a series of actual, estimated, and residual production statistics for 1948-68 as developed by equation 12. In addition, implied production estimates and residuals are shown for the same period. Table 7 presents similar information for 1969-71.

RESULTS AND EVALUATION

This section provides an evaluation of the accuracy of the models developed in the previous section. Since absolute criteria do not exist for either accepting or rejecting an economic model, the evaluation here will consider (1) probability; (2) results of this study compared with results of other studies; and (3) estimates of production as compared with actual production over both the historical period (1948-68--these data were used to calculate the coefficients) and for 1969-71, years outside the range of input data.

From the preceding section, the standard deviations were 104 kilograms for the yield model; 319,000 hectares for the acreage model; and 851,000 tons for production. These standard deviations translate into 9 percent, 4 percent, and 9 percent, respectively, of the comparable 1968 values. In terms of probability, if a yield projection is 1,000 kilograms per hectare, one can be reasonably sure that the actual yield will be between 896 and 1,104 kilograms per hectare. The chance of being wrong is approximately one out of four. Similarly with the same probability, if equation 12 gives an area projection of 8 million hectares, the actual area will fall between 7.7 and 8.3 hectares. With a production estimate of 10 million tons, actual production will fall between 9.15 million and 10.85 million tons.

Results from this study compare quite favorably with results from other studies (see app. C). In Perrin's study, the best equation of winter wheat yield in Kansas resulted in an R^2 of 0.82 and a standard deviation of 3.2 bushels per acre (17). Winter wheat yields averaged 22 bushels per acre during 1962-66. Thus, the 3.2 bushel standard deviation represents a 15-percent deviation.

Oury's study of wheat production in France did not tabulate the standard deviations for each of the various models tested. However, on a summary sheet he shows that his yield models have standard deviations which are approximately 6.0 percent of the current normal yield. His acreage and production model has standard deviations of 3.5 and 7.5 percent, respectively. The corresponding R^2's for the equations were 0.91 for yield, 0.94 for area, and 0.91 for production (14, p. 176, 184, 294). In terms of percentage standard deviations his results are better than results obtained in this study. However, it is likely that wheat yields in France do not vary as much as those in Turkey.

A Canadian study of wheat yields did not give either R^2 or standard deviations, However, it did show the range of estimated production to actual production. Excluding 1954, a year of extraordinary damage due to rust, the study's production estimates ranged from 96 to 122 percent of those reported by the Canadian Government (34).

A third criterion to be considered is how well the model fits the historical period and the accuracy of estimates for years outside the range of input data. Table 7 contains estimates for such years--1969-71. (The method of calculating the weather indexes is discussed in app. A.) Estimates for 1969 are quite close to actual levels as reported by the Turkish Government. For

Table 7--Comparison of predicted and actual values for wheat yield, area, and production, Turkey, 1969-71

Item	Unit	1969		1970		1971	
		Predicted	Actual	Predicted	Actual	Predicted	Actual
Yield 1/	Kilograms	1,272	1,230	1,194	1,229	1,461	5/
Area 2/	1,000 hectares	8,410	8,660	8,786	8,616	8,741	5/
Production 3/	1,000 m.t.	9,997	10,500	10,150	10,593	12,381	5/
Implied production 4/	1,000 m.t.	10,696	10,500	10,494	10,593	12,771	5/

1/ Yield projections were made using equation 10.
2/ Area projections were made using equation 11.
3/ Production projections were made using equation 12.
4/ Implied production estimates are the product of estimated yield and estimated area.
5/ Published estimates are not available.

Source: (26) and estimated.

yield, area, production, and implied production, the estimates for 1969 differ from actual levels by less than 5 percent. For 1970, the estimates are again reasonably close to reported values. For both 1969 and 1970, the implied production estimate is closer to the actual value than the single production estimate.

However, this phenomenon won't always hold true, as indicated in appendix table B-2, where a series of residuals is given for 1948-70. In this case, 11 of the 23 yield estimates differed by more than 5 percent from actual yields. Similarly, two of the area projections and 10 of the production estimates differed by more than 5 percent from recently reported values. The implied production estimates had the same record in that 14 of them differed from reported production by more than 5 percent. Thus, the record indicates that with the restrictions and methods used for this study, the two estimating methods are of approximately equal accuracy in estimating production.

In summary, it appears that in relation to the years covered in the model, to 3 years of observations outside the model, and to other studies of wheat production, the models gave relatively good results. However, the large standard error and the small differences in results from the direct and implicit estimates of production indicate that any estimates must be carefully compared with other estimates. In addition, as indicated in the previous sections, the methods and patterns of wheat production in Turkey are changing rapidly. Hence, parameters estimated with 1948-68 data may soon require reestimation to bring them more in line with the current situation.

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APPENDIX A--CALCULATION OF INDEXES FOR 1969 and 1970

Weather variables used in the yield and production equations required mean monthly temperatures and monthly precipitation for January, February, May, and June from the Ankara weather station. The monthly aridity indexes are found according to $I = 12P/(T + 10)$, where P represents precipitation in millimeters and T represents temperature in degrees centigrade. For example, the January 1970 temperature of 4.2° C, with precipitation of 47.5 millimeters, gives 5700/14.2 or 40.1. By the same method, an index value of 49.4 is obtained for February. For May and June 1970, the indexes are 6.9 and 12.0, respectively. In combining the months, they are weighted by the ratio of their variances, which for January and February is approximately 2.5:1. For May and June, the ratio is 2:1. These ratios do not change from year to year. Thus, the January-February index is 45.4--(2.5 x 47.5 + 40.1)/3.5 = 45.4. Similarly, for May and June, the value is 8.6--(2 x 6.9 + 12.0)/3 = 8.6. By the same method, the 1969 January-February index is 85.7 and the May-June index is 21.4. These values are now ready to be used in the estimation equations.

If an estimate is desired before June data are available, a June index value calculated from the long-term average temperature of 20.0 and precipitation of 30.6 can be used since they are the expected values. The resulting June index of 9.2 can then be used until June data are available.

APPENDIX B--REESTIMATION OF FINAL EQUATIONS USING USDA DATA

The model discussed in the body of this report was based on official Turkish statistics of wheat area, yield, and production. The U.S. Department of Agriculture also maintains area, yield, and production statistics for wheat in Turkey. The major difference between the USDA and Turkish statistics is that USDA carries smaller area figures. For example, the Turkish figure for 1968 wheat area is 8,250,000 hectares, compared with 7,304,000 hectares in the USDA series. The yield figures generally are the same.

To provide results in conformity to USDA statistics, equations 10, 11, and 12 were reestimated based on the USDA data. The results were as follows:

(10') $Y = 9.18 + 0.00098F - 0.0148JF + 0.0706MJ$

t = 2.84 2.04 2.40

$R^2 = 0.70$ SD = 1.074

(11') $A = -1432.18 + 0.779A_{t-1} + 110.94P - 9.73T$

t = 8.09 2.77 .57

$R^2 = 0.952$ SD = 272.75

$$(12') \quad PD = 4331.87 + 0.277A_{t-1} + 1.175F - 15.27JF + 46.62MJ$$

$$t = \quad 1.46 \quad 4.82 \quad 3.28 \quad 2.64$$

$$R^2 = 0.896 \qquad SD = 620.9$$

Where:

Time = 1950-69.
Y = Per hectare yield in quintals.
F = Fertilizer consumption in 1,000 metric ton units.
JF = Jan.-Feb., De Martoneau aridity index for Ankara.
MJ = May-June, De Martoneau aridity index for Ankara.
A = Acreage harvested in 1,000 hectare units.
PD = Production in 1,000 metric tons.
A_{t-1} = Acreage harvested the previous year in 1,000 hectare units.
P = Prices farmers received for wheat, discounted by the wholesale crop price index, lagged 1 year, Kr/Kg.
T = Trend 1950 = 1.
t = t statistic.
R^2 = Correlation coefficient.

The major difference between the equations here and those presented in the text is that in the area equations (11 and 11'), the price variable is statistically significant when USDA numbers are used, but not when Turkish data are used. However, in both cases it drops to a low level of significance in the production equation. Accuracy of the equations based on USDA data does not appear to be greatly improved although in general, the USDA data tend to show less variability than the Turkish data.

Appendix table B-1 presents the actual, estimated, and residual values that result when USDA statistics are used as the basic input data. Appendix table B-2 contains the same information for official Turkish statistics.

Appendix table B-1--Actual, estimated, and residuals for wheat yield, area, and production, Turkey, 1950-71, based on USDA data

Year 1/	Actual yield	Estimated yield 2/	Residual yield	Actual area	Estimated area 3/	Residual area	Actual production	Estimated production 4/	Residual production	Implied production 5/	Residual production
	Quintals per hectare			1,000 hectares			1,000 metric tons				
1950	9.1	8.5	0.6	4,877	4,631	246	4,082	4,134	-52	3,936	146
1951	11.5	10.4	1.1	4,850	5,241	-391	5,579	6,249	-670	5,450	129
1952	11.8	11.2	0.6	5,533	5,400	133	6,505	6,835	-330	6,048	457
1953	12.3	11.0	1.3	6,526	5,989	537	8,000	6,858	1,142	6,588	1,412
1954	7.5	8.7	-1.2	6,541	6,697	-156	4,900	5,299	-399	5,826	-926
1955	8.9	10.0	-1.1	7,060	6,897	163	6,760	6,667	93	6,897	-137
1956	8.0	9.3	-1.3	7,335	7,260	75	5,851	6,086	-235	6,752	-901
1957	9.4	11.1	-1.7	7,235	7,021	214	6,804	7,550	-746	7,793	-989
1958	10.5	9.8	0.7	6,475	7,044	-569	6,804	6,506	298	6,903	-99
1959	9.3	9.5	-0.2	6,273	6,398	-125	5,851	6,039	-188	6,078	-227
1960	11.2	9.7	1.5	6,313	6,109	204	7,076	6,266	810	5,926	1,150
1961	9.8	10.5	-0.7	6,273	6,275	-2	6,124	6,828	-704	6,589	-465
1962	10.5	9.4	1.1	6,475	6,467	8	6,804	6,131	673	6,079	725
1963	11.1	11.4	-0.3	7,082	6,703	379	7,892	7,376	516	7,641	251
1964	9.9	10.7	0.8	7,082	7,055	27	7,000	7,452	-452	7,549	-549
1965	10.4	10.9	0.5	7,123	7,334	-211	7,430	7,649	-219	7,994	-564
1966	11.4	11.2	0.2	7,163	7,234	-71	8,200	7,970	230	8,102	98
1967	12.5	11.4	1.1	7,204	7,333	-129	9,000	8,319	681	8,360	640
1968	17.5	11.2	6.3	7,304	7,322	-18	8,400	8,252	148	8,201	199
1969	11.1	11.8	-0.7	7,500	7,424	76	8,300	8,894	-594	8,760	-460
1970 6/	9.8	11.1	-1.3	8,200	7,524	676	8,000	8,884	-884	8,352	-352
1971 6/	13.0	13.2	-0.2	8,100	8,080	20	10,500	10,403	97	10,665	-165

1/ Year of harvest.
2/ Estimated by equation 10', p. 30.
3/ Estimated by equation 11', p. 30.
4/ Estimated by equation 12', p. 31.
5/ Implied production is the product of estimated area and estimated yield.
6/ 1970 and 1971 data were not used to calculate the estimation equation.

Source: Actual yield, area, and production were from the U.S. Agricultural Attache Service.

Appendix table B-2--Actual, estimated, and residuals for wheat yield, area, and production, Turkey, 1948-71, based on Turkish data

Year 1/	Actual yield	Estimated yield 2/	Residual	Actual area	Estimated area 3/	Residual area	Actual production	Estimated production 4/	Residual production	Implied production 5/	Residual production
	Kg. per hectare			1,000 hectares			1,000 metric tons				
1948	1,086	1,123	-37	4,538	4,477	61	4,867	5,388	-521	5,028	-161
1949	628	810	-182	4,008	4,930	-922	2,517	3,648	-1,131	3,993	-1,476
1950	864	818	46	4,477	4,410	67	3,872	3,408	464	3,607	265
1951	1,169	1,077	92	4,790	4,927	-137	5,600	5,384	216	5,306	294
1952	1,194	1,215	-21	5,400	5,171	229	6,447	6,685	-238	6,283	164
1953	1,248	1,183	65	6,410	5,754	656	8,000	7,040	960	6,842	1,158
1954	765	845	-80	6,405	6,662	-257	4,900	5,734	-834	5,629	-729
1955	977	1,025	-48	7,060	6,717	343	6,900	6,811	89	6,885	15
1956	872	915	-43	7,335	7,483	-148	6,400	6,725	-325	6,847	-447
1957	1,159	1,184	-25	7,157	7,411	-254	8,300	8,795	-495	8,775	-475
1958	1,147	989	158	7,450	7,285	165	8,550	7,320	1,230	7,205	1,345
1959	1,042	958	84	7,535	7,537	-2	7,852	7,428	424	7,220	632
1960	1,097	977	120	7,700	7,572	128	8,450	7,568	882	7,398	1,052
1961	907	1,107	-200	7,717	7,772	-55	7,000	8,656	-1,656	8,604	-1,604
1962	1,083	930	153	7,800	7,867	-67	8,450	7,415	1,035	7,316	1,134
1963	1,273	1,253	20	7,850	7,972	-122	10,000	9,850	150	9,989	11
1964	1,054	1,130	-76	7,870	7,978	-108	8,300	8,921	-621	9,015	-715
1965	1,075	1,154	-79	7,900	8,122	-222	8,500	9,136	-636	9,373	-873
1966	1,208	1,195	13	7,950	8,078	-128	9,600	9,460	140	9,653	-53
1967	1,250	1,208	42	8,000	8,150	-150	10,000	9,588	412	9,845	155
1968	1,154	1,158	-4	8,250	8,183	67	9,520	9,586	-66	9,476	44
1969	1,230	1,272	-42	8,660	8,410	250	10,500	9,997	503	10,696	-196
1970	1,229	1,194	35	8,616	8,786	-170	10,593	10,150	443	10,490	103
1971	--	1,461	--	--	8,741	--	--	12,381	--	12,771	--

-- Means published data not available.

1/ Year of harvest.
2/ Estimated by equation 10, p. 22.
3/ Estimated by equation 11, p. 23.
4/ Estimated by equation 12, p. 24.
5/ Implied production is the product of estimated yield and estimated area.

Source: Actual yield, area, and production figures are from (23).

APPENDIX C--REVIEW OF PREVIOUS STUDIES

Many attempts at defining the relationship between weather and crop yields have been made. Before the model discussed in this report was developed, the following studies were examined to determine which variables--both weather and nonweather--to use and to determine the level of aggregation that would give the best results.

One of the earliest studies, published in 1920, was made by Henry Wallace (32). Results of his mathematical analysis indicated that for corn yields in the Corn Belt, weather is more of an explanatory variable on the periphery than it is in the central part of the Corn Belt. Wallace suggested that results of his analysis merely indicated what was obvious--that corn is grown in the Corn Belt because the crop is well adapted to the climatic conditions there.

Following Wallace, the results of many studies of yield and climatic relationship were published. A succinct review of these can be found in Perrin (17). Most of the studies used precipitation and soil moisture as the principal explanatory variables and tended to be limited to one crop in one climatic area. Stallings developed national weather indexes in an attempt to incorporate crop production and climatic data in an econometric study (19). His hypothesis was that on experimental plots, all production variables except weather are controlled; thus it follows that on experimental plots, deviations from a normal yield are due to weather. From there it is a simple step to construct a weather index that is the ratio between the actual and the "normal" yields. Stallings's methodology, though useful for econometric techniques, is not applicable here since the index can be constructed only historically.

In development of a weather index, a significant advancement came in 1948, when C.W. Thornthwaite, a meterologist, suggested that evapotranspiration--the opposite of precipitation--is just as important to plant growth and it should be included in weather yield equations (20). In reality, he suggested a water-balance booking system, where precipitation is a credit, evapotranspiration is a debit, and the remainder is available for plant use. Palmer, another meterologist refined this hydrologic accounting procedure and computed soil moisture balances and drought indices for most areas of the United States (16).

Richard Perrin used the Palmer weather index for an intensive study of yields of selected crops in the United States (17). He developed yield-weather relationships for corn in Illinois and Iowa, for winter wheat and grain sorghum in Kansas and Nebraska, and for spring wheat in North Dakota. For the Kansas winter wheat yields, his study used selected combinations from 26 variables. The study was based on 1948-66 data. His best equation, in terms of R^2, contained variables for location within the State, a variable for time; and fall and spring weather variables, which were based on the Palmer index. He obtained an R^2 of 0.82 and a standard deviation of 3.2 bushels per acre--roughly 15 percent of recent yield levels.

Oury's study of wheat and feed grain production in France was the first that attempted to use the De Martoneau aridity index (14). The study--based on 1946-61 data--used weather, technological, and economic variables to develop models for yield, area, and production of wheat and feed grains.

Oury developed two series to represent weather data. One was a weighted average (weighted by production for 30 stations scattered throughout France). The other was a simple series from the Paris weather station since Paris is the center of the wheat growing region of France. When compared, the two series gave very similar results. Oury used the simpler series for his prediction models. He was able to isolate what he called a "winter-effect" variable to estimate the proportion of wheat that had to be replanted in the spring. Spring replanting has a depressing effect on yields.

On his yield equation, Oury obtained an R^2 of 0.92 and a standard deviation of 145 kilograms. For his area equation, R^2 was 0.93 and the standard deviation was 144,000 hectares. An R^2 of 0.91 and a standard deviation of 797,000 tons were obtained on his production equation.

Doll, writing in 1967 and using Missouri corn yields, had an objective of showing how a weather index could be constructed (4). He used 8 weeks of data for 37 Missouri weather stations for the years 1930-63 to construct an index of the influence of weather on corn yields. When the index was coupled with a variable for technology (he used a cubic time trend), it explained 90 percent of the variation in corn yields. He suggested that about 66 percent of the variation could have been explained by weather alone. The fact that his weather stations were not randomly selected kept Doll from performing the usual statistical tests.

A study of the effects of weather on the Canadian wheat crop used three types of weather data, soil moisture at the start of the growing season, precipitation during the 3 main growing months, and potential evapotranspiration during the same months (34). Potential evapotranspiration was calculated from maximum air temperature, minimum air temperature, and solar radiation at the top of the atmosphere. The study used 65 weather stations scattered over the three Prairie Provinces as its principal source of data. Data covered 1952-66, with 1954 deleted because a severe rust epidemic that year diminished yields more than would be expected from poor weather alone.

Williams, the author of the study, made no statistical tests. He did not specify why. His results indicated that inclusion of potential evapotranspiration gave significantly better results than equations which considered precipitation only. Average error (not to be confused with standard error) for the estimates based on precipitation only was 10 percent. Average error for the estimates based on precipitation and potential evapotranspiration was 4 percent.

The above studies gave no clear indication of the degree of aggregation that is best. Oury obtained good results with one station and national yields, while the Canadian study used 60 stations and district yields. Oury's study indicated that winter weather can have a strong influence on yields. Doll's work emphasized the importance of including a variable to account for evapotranspiration from the soil.

Appendix table D-1--Selected indicators of mechanization in Turkish agriculture, 1946-70

Year	Tractors	Grain drills	Combines	Iron plows	Tractor plows	Total iron plows	Wooden plows
		100 units			1,000 units		
1946	14	--	--	500	--	--	--
1947	16	--	--	600	--	--	--
1948	18	117	3	684	4	688	1,625
1949	92	--	--	700	--	--	--
1950	166	--	--	750	--	--	--
1951	240	--	--	800	--	--	--
1952	314	162	32	853	31	884	1,982
1953	357	208	45	900	36	936	1,996
1954	377	203	47	958	38	996	2,031
1955	403	249	56	1,026	42	1,068	2,124
1956	437	261	60	1,033	45	1,078	1,916
1957	441	270	65	1,012	46	1,058	1,968
1958	425	297	66	1,059	46	1,105	2,112
1959	419	301	62	1,129	46	1,175	2,016
1960	421	350	55	1,159	47	1,206	1,991
1961	425	347	56	1,169	44	1,213	2,065
1962	437	399	61	1,210	47	1,257	2,087
1963	508	398	59	1,237	52	1,289	1,963
1964	518	416	67	1,323	55	1,378	1,981
1965	547	434	65	1,380	62	1,442	2,031
1966	651	446	72	1,445	73	1,518	2,085
1967	750	535	78	1,446	80	1,526	2,064
1968	855	506	82	1,447	90	1,537	1,984
1969	961	654	83	1,447	119	1,566	1,908
1970	1,059	648	86	1,552	125	1,677	1,995

-- Means published data not available.

Source: (23, 26).

Appendix table D-2--Consumption of commercial fertilizers, Turkey, 1947-70

Year 1/	Gross 2/ N 20%	Gross 2/ P 15%	Gross 2/ K 48%	Gross 2/ Total*	Total nutrients 3/ N	Total nutrients 3/ P	Total nutrients 3/ K	Total nutrients 3/ Total *	Nutrients per hectare 4/ N	Nutrients per hectare 4/ P	Nutrients per hectare 4/ K	Nutrients per hectare 4/ Total	Area sown
	1,000 metric tons								Kilograms per hectare				
1947	4	5	1	10	1	1	--	2	.106	.106	---	.225	8,902
1948	6	6	2	14	1	1	1	3	.106	.106	.106	.317	9,477
1949	21	6	4	31	4	1	2	7	.445	.111	.222	.779	8,990
1950	29	13	--	42	6	3	--	9	.608	.304	--	.912	9,860
1951	20	23	--	43	4	4	--	8	.377	.377	--	.755	10,600
1952	27	34	7	67	5	5	3	14	.425	.425	.255	1.189	11,775
1953	46	31	5	83	9	5	2	17	.691	.384	.154	1.306	13,021
1954	21	40	21	82	4	6	10	21	.303	.454	.757	1.590	13,208
1955	52	84	1	138	10	13	1	25	.704	.915	.070	1.760	14,205
1956	44	26	12	82	9	4	6	19	.618	.275	.412	1.305	14,556
1957	48	34	--	82	10	5	--	15	.695	.347	--	1.042	14,392
1958	46	24	--	70	9	4	--	13	.610	.271	--	.881	14,764
1959	118	58	--	176	24	9	--	33	1.598	.599	--	2.197	15,020
1960	46	60	1	107	9	10	1	19	.588	.653	.065	1.241	15,305
1961	140	77	--	217	28	12	--	40	1.851	.793	--	2.644	15,128
1962	180	105	10	295	36	17	5	58	2.374	1.121	.330	3.824	15,167
1963	187	219	21	426	37	35	10	82	2.422	2.291	.655	5.368	15,276
1964	258	265	9	532	52	42	4	98	3.319	2.733	.260	6.377	15,367
1965	349	443	11	803	70	71	5	146	4.642	4.643	.327	9.546	15,294
1966	468	546	13	1,027	94	87	5	186	6.083	5.630	.324	12.036	15,454
1967	676	847	15	1,538	135	136	8	279	8.702	8.766	.515	17.985	15,513
1968	985	1,250	20	2,225	197	200	10	403	12.532	12.987	.649	26.169	15,400
1969	1,225	1,338	24	2,487	245	214	12	471	15.459	13.503	.757	29.719	15.848
1970 5/	1,165	1,227	44	2,436	233	184	22	439	14.946	11.803	1.411	28.160	15,589

-- Means less than one metric ton.
* Totals may not add because of rounding.

1/ Crop year basis.
2/ All fertilizer applications were converted to the standard percentages listed. Thus, fertilizer applied on the 1948 crop was equivalent to 14,000 tons of fertilizer consisting of 6,000 tons of 20 percent nitrogen, 6,000 tons of 16 percent phosphate, and 2,000 tons of 48 percent potassium fertilizer.
3/ Total nutrients consumed are simply the fertilizer equivalent times the relevant percentages. Thus, in 1948, the equivalent of 1.2 (6 x 0.2) million tons of nitrogen was consumed.
4/ Nutrients per hectare are simply total nutrients divided by the area sown.
5/ Estimated by the U.S. Agency for International Development.

Source: (23, 26, 27)

Appendix table D-3--Average annual wheat and barley prices, selected wholesale price indexes, and deflated wheat prices, Turkey, 1946-69

Calendar year	Wheat price 1/	Support 2/ price	Barley price 1/	Wholesale price index 3/: General	Wholesale price index 3/: All crops	Wholesale price index 3/: Livestock	Deflated wheat price: General	Deflated wheat price: All crops	Deflated wheat price: Livestock
	Kurus/Kg. 4/						Kurus/Kg. 4/		
1946	20.9	--	13.5	87	94	71	24.0	22.2	29.4
1947	21.8	--	13.2	88	90	84	24.7	24.2	26.0
1948	25.8	--	16.6	94	94	86	27.4	27.4	30.0
1949	28.7	--	19.0	102	108	88	28.1	26.6	32.6
1950	28.4	22	16.3	92	98	80	30.9	28.9	35.5
1951	27.8	22	17.8	97	100	88	28.6	27.8	31.6
1952	28.4	30	19.0	98	100	103	29.0	28.4	27.6
1953	29.9	30	21.7	101	94	107	29.6	31.8	27.9
1954	31.9	30	25.5	111	108	120	28.7	29.5	26.6
1955	33.2	30	26.2	120	113	127	27.7	29.4	26.1
1956	35.1	30	29.6	140	138	151	25.1	25.4	23.2
1957	44.7	40	37.6	166	169	185	26.9	26.4	24.1
1958	44.9	40	36.2	191	173	251	23.5	26.0	17.8
1959	51.7	50	43.2	228	208	280	22.7	24.9	18.5
1960	59.1	50	48.5	241	226	245	24.5	26.2	24.1
1961	72.7	64	53.6	247	254	231	29.4	28.6	31.5
1962	82.4	75	59.0	261	283	258	31.6	29.1	31.9
1963	82.1	75	58.8	272	292	290	30.2	28.1	28.3
1964	81.4	75	58.6	270	265	325	30.1	30.7	25.0
1965	85.8	75	65.1	292	290	342	29.4	29.6	25.1
1966	89.9	80	71.3	306	297	372	29.4	30.3	24.2
1967	89.9	80	70.7	330	299	432	27.2	30.0	20.8
1968	91.7	80	74.2	346	311	426	26.5	29.5	21.5
1969	97.2	85	80.4	367	335	444	26.5	29.0	21.9

-- Means published data not available.

1/ Price received by farmers.
2/ Support price of the Turkish Soils Products Office (TMO).
3/ 1950-54 equals 100.
4/ At current rates, 1,400 Kurus equal approximately U.S. $1.

Source: Wheat and barley prices (23). Support prices prior to 1954 from (1); for 1954-66 from (7); and after 1966, from unpublished reports from the Agricultural Attache. Wholesale price indices from (24).

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