TRENDS OF YIELD IN MAJOR WHEAT REGIONS SINCE 1885

PART II. IRREGULAR, STABLE, AND DECLINING TRENDS

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This study is the second of two which constitute a moderately comprehensive survey of trends of average wheat yield per acre in most regions outside of Soviet Russia, China, and Turkey and neighboring Asiatic countries. "Trend" is defined throughout as the course of a weighted nine-year moving average of annual yield per acre. The first of these two studies appeared as the issue of WHEAT STUDIES for November 1937.

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In that study fourteen major wheat regions were defined and classified as regions of characteristically rising trend (five), irregular trend (four), and stable or declining trend (five); and the diversity of yield-trend as between regions was emphasized. Consideration was then given to the interacting influences that might be expected to affect the slope and conformation of trend. Six types of influence were distinguished: inaccuracies in basic statistics; geographical shifts of wheat acreage within the region; the initial level of yield per acre; changes in the environment of the wheat plant due to natural causes (pests, weather); man-made changes in this environment, chiefly disease controls, rotations, fertilizers, mechanical devices, and regulation of water supply; and changes in types and varieties of wheat grown.

With particular reference to these six types of trend-influence, the first study then reviewed successively the five regions where trends of yield have risen since 1885. These regions were Northern Europe, France, Italy, Eastern North America, and the United States Soft Winter region. It was found that the major part of the trend-increase in yield in all of these regions was assignable to man-made improvement of agricultural techniques, among which wider use of fertilizers and the development and spread of improved wheat varieties were most prominent. But some of the trend-increase in each region resulted from what may be regarded as "accidental" influences—either the sequence of stretches of bad and good weather for wheat, or statistical inaccuracies, or both. In three regions, increase of yield was hampered by internal shifts of acreage, but in two the shifting was favorable to yields. Initial levels of yield seemed relatively unimportant; only in a few areas were they so high early in the period as to restrain increase of yield, but at the end of the period yields were presumably closer to an ill-defined upper limit than they were fifty years before.

The present study proceeds to review the trends of yield in the four regions of characteristically irregular trend and the five regions of stable or declining trend, and concludes with an analysis of trend of yield in the fourteen regions taken as a group—essentially the "world ex-Russia." The regions of irregular trend are Australia; South America, including Argentina and Uruguay; the Pacific Northwest of the United States, including Washington, Oregon, and Idaho; and India. The regions of stable or declining trend are Southeastern Europe, covering territory now lying within the eastern half of Czechoslovakia, and Hungary, Rumania, Bulgaria, Yugoslavia, and Greece; the Western Mediterranean, including Spain, Portugal, Morocco, Algeria, and Tunis; the United States Hard Winter region—Nebraska, Kansas, Oklahoma, Texas, Wyoming, Colorado, and New Mexico; the United States Spring Wheat region—the Dakotas, Minnesota, and Montana; and the three Prairie Provinces of Canada—Manitoba, Saskatchewan, and Alberta.

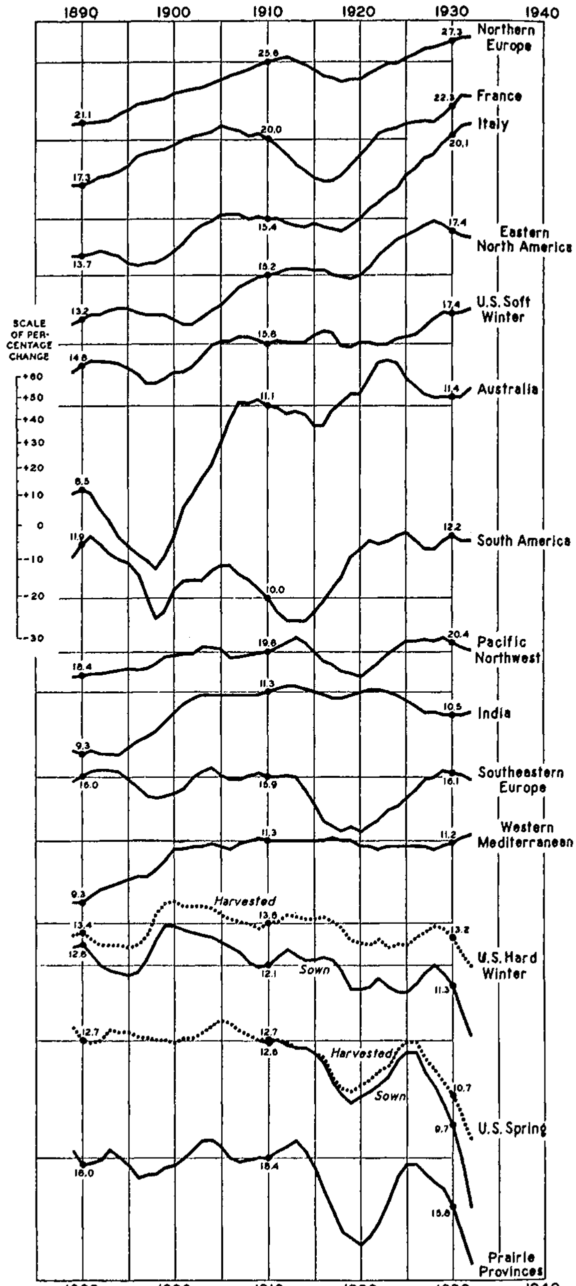
As basic reference material we reproduce, with some modifications, three charts that were presented in the earlier part of the study. These give a summary view of trends of yield in all fourteen regions (Chart 1); and they afford comparisons of trends of yield, annual yields, and annual acreage in the regions respectively of irregular trends (Chart 2) and of stable and declining trends (Chart 3) that are discussed subsequently.

The modifications are of two sorts. So far as possible, we now present in Charts 2 and 3 revised statistics for 1936, and include statistics for 1937 that were mostly not available when the earlier study was prepared. Moreover, we now present the data for two regions (United States Hard Winter and United States Spring) on the basis of sown acreage and yield per acre sown, rather than on the basis of harvested acreage and yield per acre harvested as in Chart 5 of WHEAT STUDIES for November 1937. This change permits closer and more exact comparison of trends of yield among the nine regions of irregular, stable, or declining trends. The data concerning five other regions were already on the basis of sown acreage (Australia, South America, India, the Prairie Provinces). For two other regions, Southeastern Europe and the Western Mediterranean, the data used are on the basis of harvested acreage but would closely approximate data based on sown acreage, because abandonment is unimportant. Finally, the data on harvested acreage used for the Pacific Northwest are best for comparative purposes, since farm practice there involves resowing of winterkilled wheat with spring wheat (p. 233, n. 2).

The difference between trends of yield per sown and per harvested acre in the two regions affected by this change of basis is indicated on a logarithmic scale in Chart 1, and on arithmetic scales in Charts 10 (p. 243) and 13 (p. 251). The difference between acreages harvested and sown in these two regions also appears in Charts 10 and 13. Of course the levels of yield per sown acre are lower than the levels of yield per harvested acre; and in general, on account of the extraordinarily heavy abandonment of sown acreage in these regions in recent years of drought

CHART 1.—TRENDS OF WHEAT YIELD PER ACRE IN FOURTEEN REGIONS, FROM 1885*

(Bushels per acre; weighted nine-year moving averages; logarithmic vertical scale)



* Regions defined in WHEAT STUDIES, Nov. 1937, XIV, 72.

or rust, the trends of yield per sown acre decline more steeply than the trends of yield per harvested acre.

The history of regional trends of wheat yield per acre presented in these studies provides a substantial basis for analysis of probable future developments either within the several regions or in a "world" representing the regions grouped together. But the subject of probable future developments is wide in scope, and consideration of it in the concluding section is not exhaustive.

CHART 2.—IRREGULAR REGIONAL TRENDS OF WHEAT YIELD PER ACRE, AND YIELD AND ACREAGE ANNUALLY, FROM 1885

(*Bushels per acre; million acres*)

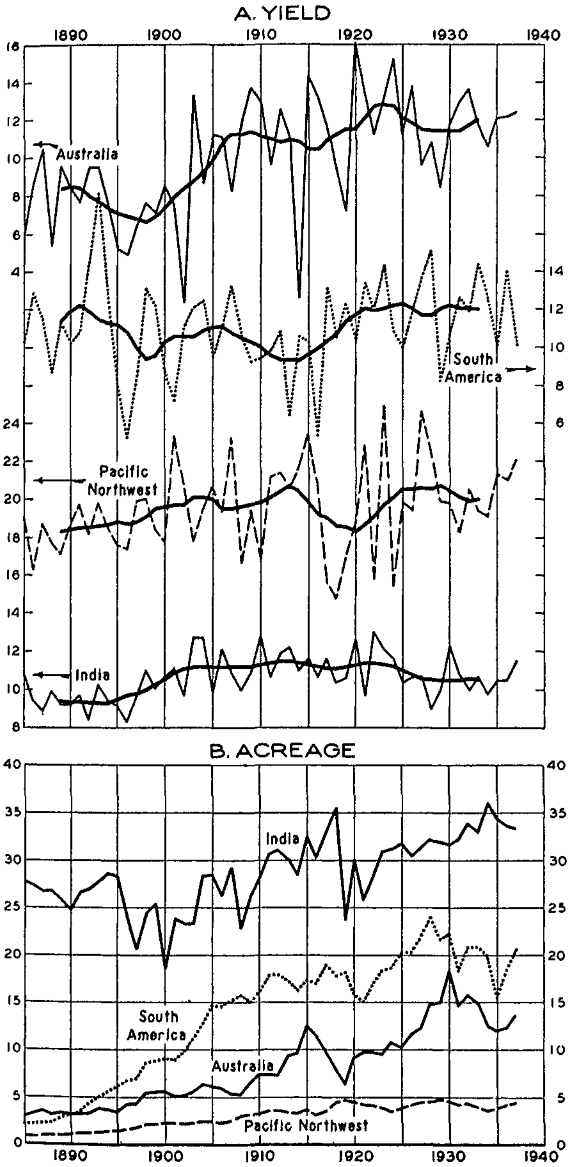
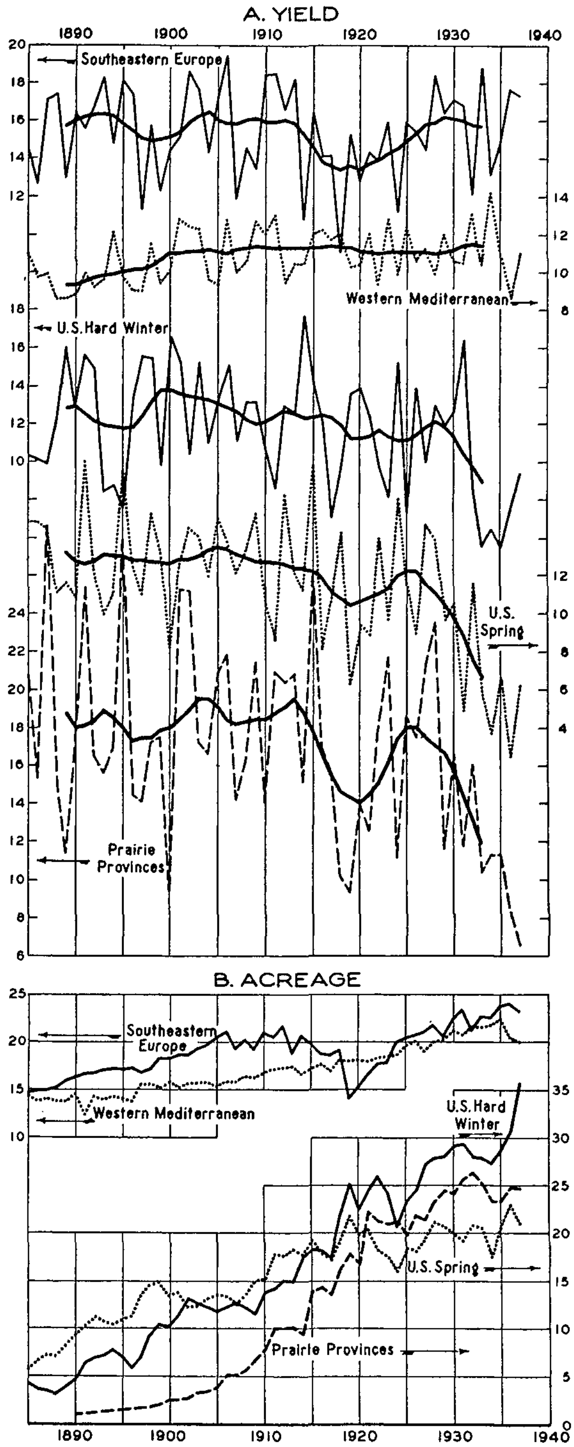


CHART 3.—STABLE AND DECLINING REGIONAL TRENDS OF WHEAT YIELD PER ACRE, AND YIELD AND ACREAGE ANNUALLY, FROM 1885

(*Bushels per acre; million acres*)



I. IRREGULAR TRENDS

Four of the fourteen wheat-producing regions show trends of yield—that is, the course of weighted nine-year moving averages—that have been classified as irregular. In large degree the irregularities appear, on analysis, to reflect changes in weather conditions, over which man has no control. But in two regions, Australia and South America, the evidence suggests that reversal of trend independent of the weather, and also of the second "accidental" influence, inaccuracy of statistics, occurred in the course of the past half-century. Improved methods of production were so timed and so extensively adopted as to reverse an early decline and to offset adverse effects of great expansion of acreage to low-yielding land. These two regions may be said to rank with those characterized by persistent increase of yield per acre, although the increase was not in evidence throughout all of the period under review. In the other two regions, the Pacific Northwest and India, increase of yield independent of the accidental effects of weather and imperfect statistics appears to exist but is of small magnitude—so small that the trends have been approximately horizontal.

The trend-increase of yield (abstracting from weather and statistical inaccuracies) involved enlarged use of fertilizer in Australia but not elsewhere. Wider use of fallow and better management of it were important in Australia and the Pacific Northwest, but not in South America and India. Improvements in minor mechanical methods were significant except in India. Improved crop rotations (excluding fallow) seem to have had little effect except in Argentina. Improved varieties helped to increase yields in all regions. Internal shifts of acreage, on the other hand, affected yields adversely except in India; but this region was the only one where wider use of irrigation can have had much effect.

AUSTRALIA

Australia, at present one of the world's large wheat-surplus areas, is a country still in a stage of expanding agricultural development. This is suggested not only by the great increase of wheat acreage—from 3 to 18 million acres between 1885 and the peak in 1930—recorded in Chart 2 (p. 225), but also by the fact that the total area devoted mainly to agriculture is estimated to have risen from 32 to 46 million acres in as recent a period as 1923–33.

The present wheat belt, confined to the southern and cooler half of the continent, lies mainly in the southeast. Here it extends in semicircular form on the interior slopes of coastal mountains from the southern part of Queensland southwesterly through New South Wales and Victoria and thence northwesterly into the coastal plains of South Australia. Westward for 800 miles there is a gap; then emerges the smaller belt of Western Australia, running from southeast to northwest.

Most of the wheat belt lies within rainfall zones of 10 to 25 inches, between the moister coastal plain and the drier interior desert. The climate is of the Mediterranean type; rainfall is heaviest in the mild winter and the summer is dry and hot. Practically all of the wheat is fall sown and of white-berried types. It does not, however, go into a dormant period as do the winter wheats of more severe climates; consequently it has a shorter growing period and a habit of growth resembling that of spring wheat, with relatively little tillering.[1] The low average level of yield per acre in Australia reflects shortness of the growing season as well as dryness of climate.

The rainfall is unreliable, more so in the larger eastern belt than in the smaller western one; and this gives rise to wide annual fluctuations of yield per acre. A rough impression of the fluctuations in weather conditions and yield and their relationship can be gained from the facts that the seven years of lowest Australian yields between 1885 and 1930 averaged only 5.2 bushels and were associated with June–September rainfall at Adelaide, South Australia, averaging 8.4 inches; whereas the seven years of the best yields (trend consid-

[1] H. C. Forster and A. J. Vasey, "Investigations on Yield in the Cereals. I, Census Studies 1927–29," *Journal of Agricultural Science* (London), July 1931, XXI, 395, 399.

ered) averaged 13.8 bushels and were associated with June–September rainfall at Adelaide averaging 12.5 inches. Normal rainfall at Adelaide in these four months is about 10.4 inches. Rainfall at this single point is not a close indication of rainfall throughout the wheat belt, though there is relationship. Barkley strongly emphasizes the importance of August–September rainfall for Victorian yields.[1]

The low level and unreliability of rainfall invoke the use of fallow to conserve moisture;[2] and at present in settled areas, wheat is usually grown on fields previously fallowed except when a favorable price position stimulates sowing of wheat on wheat stubble or on land ordinarily pastured. On the pioneer fringes, however, wheat often follows wheat for several years and is also sown annually on newly broken ground. There is as yet no truly typical rotation of crops. Perhaps the commonest system is wheat after fallow, modified in some places to fallow, wheat, wheat; or to fallow, wheat, oats or barley or grass or peas. Only in the older and moister regions is the fallow commonly replaced by a legume or an intertilled crop, and only here have rotations including fallow been extended to four-year or five-year courses. In the four principal wheat-producing states, wheat recently (averages 1929–30 to 1933–34) occupied half of the land classified as under crop and fallow; this was true also at the turn of the century (1900–01 to 1904–05). But in the earlier period the land in fallow was barely a third as large as the wheat acreage, while in the later period it was three-fourths as large.

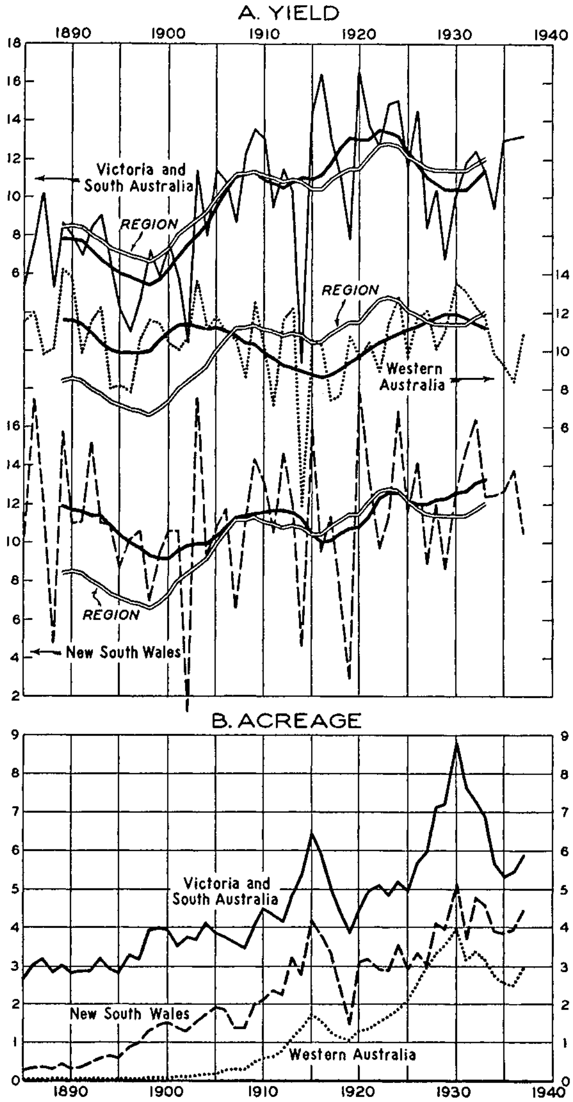
[1] H. Barkley, "The Victorian Wheat Harvest. Climatic Controls and World Prices," *Wheat and Grain Review* (Melbourne), Aug. 6, 1927, pp. 8–11.

[2] In recent years there has been a tendency to ascribe the beneficial effect of fallow upon wheat yields less to moisture conservation and more to other factors, partly unknown but partly representing suppression of weed growth and stimulation of nitrification in the soil. See S. M. Wadham, "The Wheat Industry," in "An Economic Survey of Australia," *Annals of the American Academy of Political and Social Science*, November 1931, CLVIII, 55; and Australia, Royal Commission on the Wheat, Flour and Bread Industries, *Second Report* (Canberra, 1934–35), p. 196.

The average wheat yield for Australia, measured in terms of weighted nine-year averages centering in the years named, moved from 8.5 bushels in 1890 to only 6.6 bushels

CHART 4.—TRENDS OF WHEAT YIELD PER SOWN ACRE IN SUBDIVISIONS OF AUSTRALIA, AND YIELD AND ACREAGE ANNUALLY, FROM 1885*

(Bushels per acre; million acres)



* Subdivisions defined in accompanying text. The hollow lines represent trend of yield in Australia, as in Chart 2.

in 1898, and then rose to 11.1 bushels in 1910 and to 11.4 bushels in 1930 (Charts 1 and 2, pp. 224, 225). By states the trends were different (Chart 4); but average levels of yield in the four principal wheat states[1] have been so similar that shifts in the proportion of the acreage lying in one state or the other have not been a dominant influence on the trend of average Australian yield.

The more significant influence has been progressive penetration of the wheat acreage into drier and lower-yielding regions within each state, which is not shown in the chart. This tendency, coupled with a tendency toward depletion of soil fertility through continuous cropping first in one newly settled area and then another, has affected yields adversely throughout the past half-century. Increase of yield occurred in spite of these adverse factors.

The sequence of good and bad seasons also seems to have been adverse to trend of yield. Perhaps the general average of 1890 (8.5 bushels) represents an approximately normal distribution of seasons. But the continuing decline of yield to 6.6 bushels around 1898 represents in part an exceptional scattering of dry years (1895, 1896, 1897, 1902, possibly 1899). Even with normal weather, average yields might have fallen lower in 1898 than in 1890, continuing a downward trend in evidence since 1865; but they would probably not have fallen below 7.5 bushels. There seems little ground for supposing that the average yield around 1910 (11.1 bushels) occurred in a period of abnormal weather; but the depressions centering in 1915–16 and 1928–31[2] seem to have been occasioned partly by exceptional scatterings of dry years, while the bulge of yield centering in 1923 in part reflects an unusually favorable stretch of years.

A curve of Australian yield corrected for weather might therefore start about like that in Chart 4 based on recorded statistics, fall less to 1898, rise to about the same 1910 level, and continue to rise more slowly after 1910 but perhaps without reaching even by 1935 the level attained by the recorded trend in 1922–24. It seems not too much to say that an increase of "normal" yield (abstracting from weather) from around 7.5 bushels in the middle 'nineties to 12 bushels or a little more in 1930 has been achieved in Australia in the face of great expansion of wheat acreage to less and less favorable climatic regions. This must be counted as a remarkable achievement; at the same time it is clear that the increase of "normal" yield from 1910 to 1930 was not of large magnitude.

The ways whereby improvement of yield were attained are in general fairly clear. If one compares the levels of 1890 and 1930, neither statistics, the chance of distribution of weather, geographical shifts of acreage, complication of crop rotations, irrigation, drainage, nor larger use of barnyard manure seem to have had significant favorable effect; and the shifts of acreage and distribution of weather were unfavorable. The initial level of yield was so low that there was much room for improvement. But the principal favorable influences were enlarged use of commercial fertilizer, development and adoption of superior new varieties, wider use of fallowing, and improvement of mechanical methods. To these may be added a general tendency toward decline in the proportion of the wheat acreage sown on newly broken land.[3]

In its timing, perhaps the use of artificial fertilizer—very largely phosphates, since the need of Australian soils for nitrogen or potash, under conditions of low rainfall, is much

[1] Chart 4 includes in the Australian total data for Queensland, Tasmania, and the Federal Capital Territory which are not shown separately. These areas produce so little wheat that developments within them are of practically no importance in their effect on total Australian acreage or yield per acre.

[2] These depressions of yield were also more or less synchronous with the war and with years of financial crisis. In parts of these periods there was incentive both to expand the wheat area to stubble and pasture, and to reduce per acre applications of artificial fertilizer.

[3] Australia is peculiar among the newly developed wheat regions of the world in that, other things equal, increase of yield would be expected to result from a decline in the fraction of the wheat area grown on newly broken land. In other regions, where new breaking occurs on treeless grassy plain (as in central North America), farmers in a given locality obtain high yields for the first few years and relatively lower yields thereafter; so that a high proportion of new breaking in the regional wheat area tends, other factors equal, to maintain the level of regional yield, and a declining proportion of new breaking to reduce it. In Australia, however, the new land is mostly covered with woody scrub ("mallee"), yields on the new breaking are low, and the farmer tends to secure higher yields in the course of time as the soil is brought into better tilth through elimination of roots and stumps.

less[1]—exerted the first large influence. In the middle 'nineties, little or no artificial fertilizer was used even in the oldest wheat-producing state, South Australia; by 1905 it was there being used on more than 65 per cent of the crop land, at a rate of 85 pounds per acre, and by 1910 on 80 per cent of the crop land at about the same rate. In this state, the use of artificial fertilizer became practically general within 10 to 15 years following 1895; and the period after 1910 does not indicate comparably rapid expansion either in the percentage of crop land fertilized (91 per cent at the peak in 1929–30) or in the quantity applied per acre (92 pounds at the peak in 1926–27). In other states, the use of artificial fertilizer may have lagged somewhat; but there is reason to suppose that by 1910 it was widely generalized at least in the eastern wheat belt.

Widespread adoption of more prolific varieties perhaps came somewhat later than wider use of artificial fertilizer. The new variety most widely adopted was Farrer's "Federation," which was first distributed in 1900. It withstood the general drought of 1902 well and spread rapidly thereafter. It occupied about 60 per cent of the Victorian wheat acreage by 1924,[2] and other new varieties found a place in the balance of the acreage. Federation has since been extensively displaced by still newer varieties.[3]

The fact that these influences were not strongly operative before 1895, coupled with their rapid effect in the early years of the century and the incidence of bad weather in the middle 'nineties, accounts broadly for the continuing decline of yield trend to 1898 and its rapid advance to approximately 1910. Increase of the proportion of the wheat acreage grown on fallowed land and decline in the proportion grown on new breaking occurred simultaneously. But these were in the nature of persisting trends, and interrupted particularly by the war-time and middle postwar bulges of wheat acreage. More or less synchronously came improvement in methods of managing the fallow, themselves promoted by widening scientific knowledge as well as by invention and adoption of new machinery or improvement of older types. All of these influences continued operative after 1910—adoption of the fallow and better mechanical methods perhaps standing more in the foreground than before, with wider use of artificial fertilizers and of new varieties perhaps less conspicuous; but the period between 1910 and 1930 witnessed less spectacular changes of cultural practices than occurred in the preceding twenty years.

No satisfactory basis appears for appraising the relative quantitative effects of the several influential factors. In restricted localities where there has been no great change in the area sown to wheat, increases of yield have been larger than in whole states or in all of Australia. Thus in Moira County of Victoria, the average yield per acre rose from about 10.1 bushels in 1890–99 to 15.1 bushels in 1925–32[4]—an increase of 5 bushels or 50 per cent certainly assignable mainly to improved methods of cultivation and new varieties and not in large measure to vagaries of the weather, for there were bad years in both periods. In Victoria as a whole, where the acreage more than doubled between these periods, the average yield rose from 8.2 to 11.8 bushels, an increase of 3.6 bushels or 44 per cent.

Our impression is that fundamental persisting influences will bring about a gradually rising trend of yield in Australia for some years to come. Expansion of acreage into the dry interior seems unlikely to proceed so

[1] A. E. V. Richardson, *Wheat and Its Cultivation* (Victoria Dept. Agr. Bull. 55, 1925), pp. 25–26.

[2] *Ibid.*, p. 163.

[3] Thus in New South Wales between 1925–26 and 1929–30 there was substantial decline in the areas sown to the varieties Federation, Hard Federation, and Canberra, but substantial increase in the sowings of Waratah, Yandilla King, Turvey, Nabawa, Bena, Marshall's No. 3, and Penny. The first three varieties constituted about 52 per cent of the total acreage in 1925–26, but only 24 per cent in 1929–30. See New South Wales, *Report of the Department of Agriculture for the Year Ended 30th June, 1930* (Sydney, 1931), p. 34.

[4] H. C. Forster, quoted in *Wheat and Grain Review* (Melbourne), Feb. 9, 1934, p. 10. In the Wimmera district of Victoria, where also the acreage remained about stable, it has been shown that yields rose from 7.6 to 19.1 bushels between 1897–1901 and 1915–20, an increase of 151 per cent; see H. A. Mullett, "A Study of Wheat Yields in the Wimmera and Northern Districts," *Journal of the Department of Agriculture of Victoria*, June 1922, XX, 321–37. Mullett indicates that the Northern district of Victoria, in which lies Moira County, lagged behind the Wimmera district in adoption of fallow and artificial fertilizer.

rapidly as to offset the discovery and adoption of improved varieties and agricultural techniques.

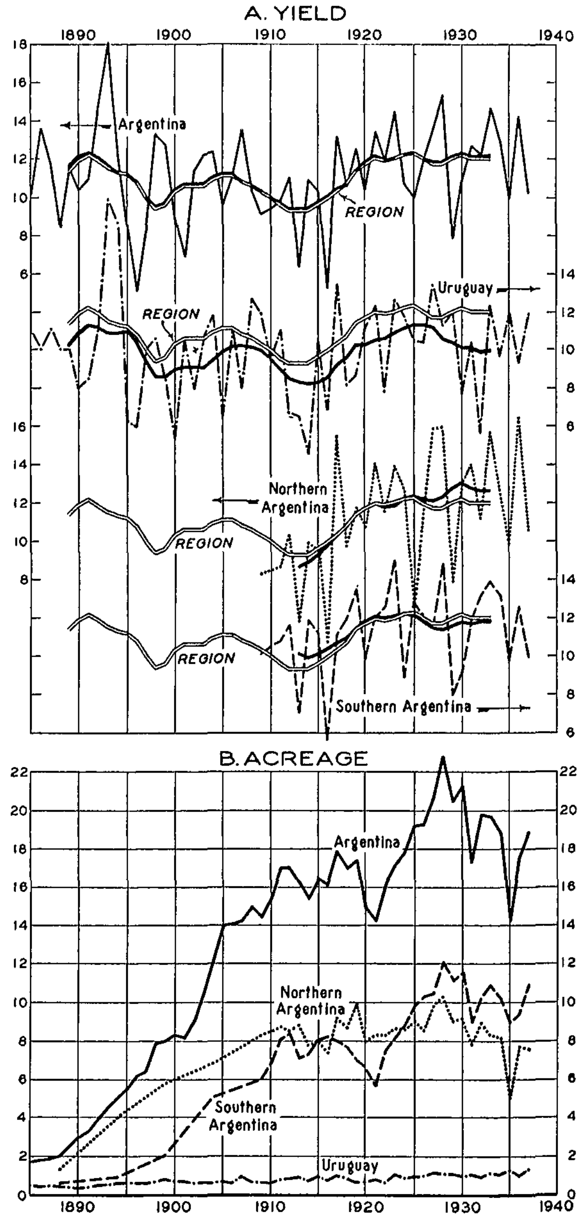
SOUTH AMERICA[1]

The wheat belt of South America lies in a climate cooler and moister than that of the Australian wheat belt, and on soils of a flat plain (the "Pampa") inherently more fertile. Hence, although Argentina is also a country still in an expanding phase of development,[2] two wheat-growing practices of major importance in Australia play practically no part in Argentina. These are fallowing and use of fertilizer. Since wheat statistics for the South American region appear reasonably trustworthy, the course of average wheat yield in this region must be explained on other grounds than inaccuracies of statistics or changes in practices of fallowing or fertilization. Irrigation and drainage are also insignificant.

Practically all of the wheat acreage of the South American region lies within rainfall zones of 15–40 inches; and only in the cooler southern extremity of the belt is much wheat sown on land that normally receives less than 20 inches. The climate is of a maritime-continental type, with seasonal rainfall heaviest in summer (in some places spring or autumn) and lightest in winter. The annual rainfall diminishes generally from northeast to southwest, and from east to west in the northerly stretches; and the historical tendency has been to extend wheat production into these drier southwestern and western districts. Some evi-

CHART 5.—TRENDS OF WHEAT YIELD PER SOWN ACRE IN SUBDIVISIONS OF SOUTH AMERICA, AND YIELD AND ACREAGE ANNUALLY, SO FAR AS AVAILABLE FROM 1885*

(Bushels per acre; million acres)



* Subdivisions defined in accompanying text. The hollow line represents trend of yield in South America as a whole, as in Chart 2.

dence of this tendency appears in Chart 5, which shows wheat acreage in Uruguay, in the three principal northern wheat-growing

[1] Literature concerning agriculture in the South American region was considerably more abundant just before and after the war than it has been in recent years. From the relatively recent literature, the following discussion draws heavily upon M. Jefferson, *Peopling the Argentine Pampa* (New York, 1926); L. M. Estabrook, *Agricultural Survey of South America: Argentina and Paraguay* (U.S. Dept. Agr. Bull. 1409, June 1926); and C. F. Jones, "Agricultural Regions of South America," *Economic Geography*, January 1928, IV, 1–30.

[2] Arable land in Argentina (land customarily sown to crops or temporarily idle or in fallow), has been estimated as about 7 million acres in 1890, 21 million in 1902, 44 million in 1909, 53 million in 1922, and 66 million in 1933. Argentina contains the great bulk of the wheat acreage in the South American wheat region as we define it here, Uruguay only a little. Both countries are net exporters of wheat, though Uruguay was a net importer in 1931 to 1933.

provinces of Argentina (Entre Rios, Santa Fé, and Córdoba), and in the two principal southern provinces (Buenos Aires and La Pampa territory). There has been greater expansion of wheat area in the southern provinces. But in order to illustrate more accurately the trend of wheat acreage toward drier land, it would be desirable to show the development of acreage in the western half of Córdoba, all of La Pampa, and the southwestern third of Buenos Aires together, in contrast with combined acreage in the parts of the South American region lying to the east. This cannot be done with the data at hand.

Nearly all of the wheat is fall sown (May–July), of many types including a little durum, but mainly red wheats ranging from soft or semi-soft in the warmer northern and eastern stretches to semi-hard or hard in the western and southern stretches. The semi-hard and hard predominate.[1] Growth of the fall-sown wheat is apparently checked more than in Australia by lower winter temperatures;[2] yet in general the winters are open with little or no snow in most parts of the wheat belt, and work on the land is feasible in the winter months. Abandonment of wheat acreage is a prominent phenomenon,[3] but only in part because of severe winter weather. The crop in some years suffers from rust, drought, hot northerly winds in the spring, excessive moisture that promotes weed growth, or the ravages of locusts.

Crop rotations, so far as they exist, are of rudimentary sort. In some districts wheat may follow corn, either crop holding the land several years; in others a common practice is linseed one year, wheat three years; in others wheat for one or several years may be followed by oats or barley one year or several. To a considerable extent wheat production is incidental to cattle husbandry. Landowners rent part of their holdings to tenants who grow wheat for four or five successive years and complete their term by sowing to alfalfa, and the land may lie in alfalfa for several years and later be sown again to wheat; the cropping with wheat is regarded as preparation for alfalfa. A rotation involving corn, wheat, and alfalfa (either, perhaps, for more than one year) has gained a foothold in some of the moister districts. In general the cropping system has involved much continued cultivation of wheat on much land.[4] The fluid system of cropping permits adaptation of acreage in the principal crops to be made easily and extensively in response to changing economic advantage, and the wheat acreage may encroach upon or yield to the acreage especially in corn, alfalfa, and linseed. Since animals are usually pastured, systematic application of barnyard manure to arable land is rare.

The trend of regional yield per acre in South America (Chart 2, p. 225, and Chart 5) declined irregularly from 1890 to 1912–14, rose rather steeply to 1921, and has since moved about horizontally. In 1930 the level of yield was only about 0.3 bushel higher than in 1890. External or accidental circumstances—the incidence of weather and pests—have rather strongly affected the conformation of the trend. If the yield in 1893 had been moderately instead of extraordinarily good, the weighted nine-year average yield centering in 1890 would have been nearer to 11.5 than to 11.9 bushels; a preponderance of exceptionally bad years in the period 1895–1902 caused a dip in the course of the moving average that would not have occurred with ordinary weather; the low levels of yield centering in 1912–14 occurred in the midst of a long stretch of seasons either somewhat or decidedly bad (1909–16); and the period 1917–23

[1] The so-called hard wheats include such varieties as Kanred and Blackhull, which are widely grown in Kansas in the United States.

[2] Wheat varieties with winter habit of growth ("invierno") occupied about 42 per cent of the Argentine wheat acreage in 1936, mostly in the southern half of the wheat belt; while varieties with a spring habit of growth ("primavera") occupied about 45 per cent, mostly in the northern half of the belt. See V. C. Brunini and N. L. Marchetti, *Las variedades de trigo en el pais...* (Comision Nacional de Granos y Elevadores Pub. 16, Buenos Aires, 1937), pp. 43–44.

[3] Statistics of acreage both sown and harvested are available for Argentina from 1909. Data for 1909–32 are given in M. K. Bennett, "World Wheat Crops, 1885–1932," WHEAT STUDIES, April 1933, IX, 266; and the series are carried currently in "Review" numbers of WHEAT STUDIES.

[4] The system of land tenure—holdings in huge blocks, whose owners prefer grazing operations to arable cultivation—has doubtless encouraged monoculture on rented land. But small owners frequently follow the same procedure.

seems to have contained more than a normal scattering of good years.

Our impression is that, abstracting from weather, the trend of Argentine yield would have started from a lower level in 1890, falling more gradually and by a smaller amount than the recorded trend until some year in the period 1910–15, thereafter rising gradually to about the level actually attained in 1930. If this impression is trustworthy, there is reason to suppose that agricultural technique improved over the period as a whole, though particularly in the latter half of the past half-century; and that the improvement sufficed more than to offset adverse effects on yield due to expansion of acreage to drier territory and continuous wheat cultivation on many pieces of land.

The principal favorable influences were probably wider adoption of improved wheat varieties; improvement of mechanical methods, among which prominent ones were substitution of sowing by drill instead of broadcast, cleaner cultivation of corn, and more efficient plowing; and, in the central stretches of the wheat belt, spread of alfalfa cultivation in semi-rotation with wheat. Our impression, not well supported by specific evidence, is that these influences operated more strongly after 1910 than before. Their full potential effect has probably not yet been exerted.

Pacific Northwest

The wheat acreage of the Pacific Northwest (Oregon, Washington, and Idaho) lies in three districts: the Willamette Valley of Oregon, west of the Cascade Mountains; the Columbia River Plateau, east of the Cascades, with its bulk in Washington, its southwesterly extension in Oregon, and a smaller eastward extension in northern Idaho; and southern Idaho far to the southwest, along the Snake River basin that runs from east to west like an upturned crescent across the state. The Willamette district, well watered and with a mild winter climate, is the oldest of these wheat-growing districts, once the most important but now the least; there wheat has lost ground both absolutely and relatively. Southern Idaho is a very dry region where more than a fourth of the wheat acreage is nowadays irrigated[1] and the rest is grown under dry-farming methods.

The Columbia River Plateau is by far the most important of these three districts. The plateau inclines from east to west, and also from north and south towards its center. In its east-central and lowest part the rainfall is deficient (8 inches or less a year) and practically no crops are grown. Toward the south, east, and north the precipitation increases with elevation, reaching 20–25 inches at the extremes of the wheat belt in the foothills of surrounding mountains. The rainfall is seasonally heavy in the winter months, light in summer; and in large degree the crops depend upon the amount of annual rainfall and perhaps especially upon rainfall in April–June.[2] Winters are colder than in Australia or Argentina.

Pasture land not suitable for cultivation occupies a substantial fraction of the land. Of the arable land (now extended not far from its limits), the great bulk is used for production of wheat grown on fallow; it is said that no other grain crop will yield so high a poundage per acre as wheat. The specialization on wheat and the relative insignificance of other crops are striking—least so on the moister peripheries of the belt and most so in the drier parts. The region regularly produces a surplus. The rotation of fallow, wheat is typical, modified in the drier stretches to fallow, fallow, wheat and in the moister stretches to wheat for two to four years successively followed by fallow, or to insertion of a few other crops like peas, beans, or alfalfa in rotations that always include wheat and usually include fallow. The topography of the land is irregular, and cultivation and harvesting are mostly with large machines drawn contourwise along moderately steeply rolling low hills. The farms are large, the farmers able and intelligent.[3]

[1] H. A. Vogel and N. W. Johnson, *Types of Farming in Idaho . . . .* (Idaho Agr. Exp. Sta. Bull. 207, May 1937), p. 27.

[2] B. Hunter, G. Severance, and R. N. Miller, *A Review of the Agriculture of the Big Bend Country* (Washington Agr. Exp. Sta. Bull. 192, September 1925), esp. p. 27.

[3] J. S. Davis, "Pacific Northwest Wheat Problems and the Export Subsidy," WHEAT STUDIES, August 1934, X, 370.

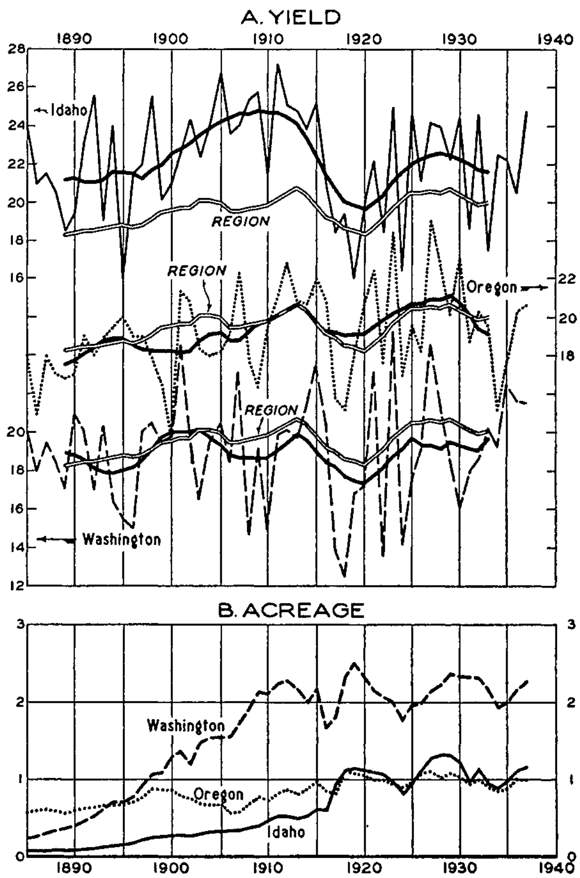
Both winter and spring wheats are grown, the winter predominating. Spring wheat tends to occupy most of the wheat acreage in the northwestern part of the Plateau, where precipitation is lighter generally and especially in the months (September–October) when winter wheat germinates, and where winter temperatures are relatively low and the snow-cover frequently inadequate.[1] But spring wheat is scattered more or less throughout the region every year, and it may occupy a large fraction of the total acreage in years of severe winterkilling and subsequent resowing with spring wheat.[2] Many varieties are grown, among them "Federation." The Pacific Northwest, like Australia a wheat-and-fallow country, has drawn heavily upon Australian experience. Australia grows white wheat from soft to semi-hard type almost exclusively; the Pacific Northwest also grows much of these types, but produces considerable wheat of red varieties.[3]

On the average for the Pacific Northwest as a whole, the recorded trend of yield was slightly upward (hollow line in Chart 6, and Chart 2, p. 225), from 18.4 bushels around 1890 to 19.8 bushels in 1910 and 20.4 bushels in 1930—an increase of only 11 per cent in 40 years. In Washington and Idaho the increase was smaller, in Oregon larger. It is possible that the statistical data in each state somewhat exaggerate the increase of yield;[4] if so, the region as a whole ranks with those of stable or declining yields rather than with those where increase of yield is unmistakable.

It seems clear also that the course of the moving average of yield in the Pacific Northwest depends somewhat on the accidental effects of weather. The operative non-accidental factors appear to have been shifts of acreage, wider use and better management of summer fallow, improved mechanical methods, and adoption of new varieties. The use of fertilizer of any sort has never been significant; and the only important change in rotations seems to have been in the alternation of wheat with fallow.

Chart 6.—Trends of Wheat Yield per Harvested Acre in Subdivisions of the United States Pacific Northwest, and Yield and Acreage Annually, from 1885*

(*Bushels per acre; million acres*)



* Subdivisions defined in accompanying text. The hollow line represents trend of yield in the Pacific Northwest as a whole, as in Chart 2.

Internal shifting of acreage in the course of general expansion was presumably strongly adverse to increase of yield. In 1890, the acreage of the region lay mainly in the well-watered Willamette Valley, and on the moister peripheries of the Columbia River Plateau.

[1] V. Roterus, "Spring and Winter Wheat on the Columbia Plateau," *Economic Geography*, October 1934, X, 368–73.

[2] Because of this prevailing practice, the harvested acreage of wheat in the Pacific Northwest is more closely equivalent to sown acreage in such regions as Australia, South America, and the Prairie Provinces than to harvested acreage in such regions as the United States Hard Winter or Soft Winter, where resowing of winterkilled wheat acreage with wheat is not common.

[3] See Davis, *op. cit.*, pp. 359–61, for discussion of the multiplicity of wheat varieties grown in this region.

[4] M. K. Bennett, "Trends of Yield in Major Wheat Regions since 1885. Part I. General Considerations and Rising Trends," Wheat Studies, November 1937, XIV, 77.

By 1910 it had declined in the Willamette district; and on the Plateau, while becoming denser in the more humid parts, had extended westward into the drier regions. This direction of expansion continued, though less rapidly, in the next two decades; and in addition a substantial acreage had appeared by 1930 in the dry-farming district of southern Idaho.[1] On the Plateau itself, there are large differences between yields in the moister and in the drier sections.[2] In view of the degree of difference in yield between sections and the direction of acreage expansion, it seems remarkable that the general regional trend of yield should have risen at all. The fact that the period included expansion of acreage to irrigated land where yield is high does not seem important, for even now probably little more than 5 per cent of the total regional acreage is irrigated, principally in southern Idaho.[3]

We see little reason to suppose that unusual weather conditions appreciably affected the average yields for periods centering in 1890 and 1930, though the presumption may be that with normal weather the yield around 1890 would have been a little higher. Dips and bulges in the course of the moving average, however, reflect weather influence in substantial degree. The seven years 1911–16 were exceptionally favorable, giving rise to a bulge of yield centering in 1913; the six-year period 1917–22 contained three very bad years and only one exceptionally good, giving rise to a depression of yield centering in 1920;[4] and the period 1930–36 contained a heavy proportion of bad years, resulting in the downward drift of the moving average after 1929. Corrected for weather influences, the regional trend would probably be smoother, and perhaps show a little less net improvement of yield between 1890 and 1930.

Abstracting from weather, it seems probable that better methods of cultivation and new varieties have come into use sufficiently to overcome adverse effects of shifts in acreage and soil depletion. Early settlers in the more humid regions often cropped the land to wheat for several successive years, with unfavorable effects upon yields; but the need for fallowing was quickly recognized.[5] Progress has probably been greater with reference to management of the fallow, especially the time of plowing and the number of cultivations, than with reference to more general adoption of it; and new and more economical implements have facilitated better management. Varieties unknown before 1912,[6] when the regional acreage had expanded to nearly 80 per cent of its 1929 peak, occupied over a third of the 1929 acreage. But in spite of cessation of the process of acreage expansion since 1919, with continued improvement of varieties and technique, there seems to have been little if any change in yield per acre that is not largely attributable to weather developments. In some districts decline in soil fertility has become evident; in the same or other districts, more or less erosion on the crests and upper slopes of the cultivated hills.[7] Maintenance or increase of yield will probably be more difficult here than in Australia or Argentina unless the drier land is withdrawn from wheat production.

[1] Dot maps of wheat acreage (1890, 1910, 1930) are conveniently available in J. H. Garland, "The Columbia Plateau Region of Commercial Grain Farming," *Geographical Review*, July 1934, XXIV, 372.

[2] Yields in Sherman County, Oregon, in the dry and warm southwest–central part of the Plateau (rainfall belt of 8–15 inches) averaged 15.2 bushels in 1929–32; whereas in Umatilla County, farther east in a cooler rainfall belt of 10–20 inches, the yield averaged 27.6 bushels. See H. D. Scudder and E. B. Hurd, *Graphic Summary of Agriculture and Land Use in Oregon. Preliminary Issue of Selected Maps and Graphs* (Oregon Agr. Exp. Sta. Circ. 114, December 1935).

[3] Perhaps the initial high level of yield in Idaho, the rising tendency up to the war, and the lower level after the war are partly explicable by early location of acreage in the moister fringe of the Plateau, subsequent expansion there and on irrigated land in the south, and postwar expansion largely to dry land in the extreme southeast.

[4] This depression, however, was associated also with swift expansion of acreage to drier land and with more or less sowing of stubble fields which would have been fallowed except for the war-time stimulus of high prices.

[5] Hunter, *et al., op. cit.*, p. 9; G. Severance, B. Hunter, and P. Eke, *Farming Systems for Eastern Washington and Northern Idaho* (Washington Agr. Exp. Sta. Bull. 244, July 1930), p. 13.

[6] Dicklow, Ridit, Federation, Hard Federation, Baart, and Albit; see J. A. Clark and B. B. Bayles, *Classification of Wheat Varieties Grown in the United States* (U.S. Dept. Agr. Tech. Bull. 459, April 1935).

[7] Severance, Hunter, and Eke, *op. cit.*, p. 5; O. E. Baker, "Agricultural Regions of North America. Part XI—The Columbia Plateau Wheat Region," *Economic Geography*, April 1933, IX, 178–79.

INDIA[1]

In India, the largest of the fourteen regions considered in this study, wheat is produced under exceptional conditions. This is the only region where winter wheat is widely grown on irrigated land, and in a climate characterized by a decided maximum of rainfall in the summer before the wheat is sown but by low rainfall during the growing season of wheat in the winter. The heavy monsoon rains prevail in June–September; then comes a rather dry period, followed by a few inches of rain in December–February and then a very dry hot period in March–May. In general, wheat is sown a few weeks after the close of the monsoon period; germinates and begins its growth on residual moisture left in the soil from the preceding monsoon or transferred to the soil by irrigation; is carried to maturity by winter rains and irrigation; and is harvested in the dry hot spring, the first of the Northern Hemisphere crops to mature. Toward the northwest the monsoon rains diminish and the winter rains increase; here wheat grows in a climate more like the Australian or South Italian.

The wheat belt runs from northwest to southeast across India, along a relatively narrow belt on the fertile alluvial plains of the Indus (west flowing) and Ganges (east flowing) rivers. A little east of the middle of this main belt, a tongue extends southward onto the Deccan plateau. Throughout the wheat belt, wheat is everywhere grown as a winter crop—frequently sown on land that has lain fallow for about nine months after a summer crop harvested the preceding October–December; sometimes on land that has lain fallow for more than a year, after a winter crop; occasionally on land that has been cropped during the preceding monsoon season, directly after the monsoon crop is removed. The system of rotation is very old, and the value of leguminous crops in rotation is well understood. These are sometimes sown mixed with wheat on the same fields, and sometimes they displace wheat for a year or two on fields usually sown to wheat for the winter crop. In the northwest, where summer crops cannot be grown because of light monsoon rains, wheat may follow wheat in the rotation for several years; but here leguminous weeds happen to grow with the wheat. Fertility is maintained partly by rotation and fallow, partly by deposits of silt on river plains during summer floods, somewhat by manure (though this, dried, is used largely for fuel), and practically not at all by commercial fertilizers. Agricultural implements are of primitive types. Neither rotations, manuring practices, nor implements appear to have changed much in fifty years.

The wheat continues to grow throughout the winter, which is not sufficiently cold to bring killing frosts or snow. Consequently its growing season is short, and in habit of growth the wheats are intermediate between the winter and spring wheats of the United States. This may help somewhat to account for the relatively low average level of Indian yields per acre. Statistical understatement of the level is also possible.[2] The wheats are both white and red, some of them rather high in protein content. In the southern tongue where the growing season between the cessation of the monsoon and the hot weather of spring is short, a good deal of durum wheat is grown.

Irrigation of wheat, from either government canals, private canals, tanks, wells, or other sources, is most practiced in the northwest (Punjab), somewhat less in the east (United Provinces), and not much in the southern tongue of the wheat belt. In recent years nearly two-fifths of the total Indian wheat acreage has been irrigated. The proportion was a little smaller just before the war, and substantially smaller in the early 'nineties. Within a given district, wheat yields average considerably higher on irrigated than on non-irrigated land. Consequently the progressive enlargement in the fraction of the wheat acreage under irrigation must have tended to increase wheat yield per acre.

The irrigated acreage is much more stable from year to year than the unirrigated acre-

[1] Based largely on data and discussion in A. and G. L. C. Howard, *Wheat in India* (Calcutta and London, n.d.); C. P. Wright and J. S. Davis, "India as a Producer and Exporter of Wheat," WHEAT STUDIES, July 1927, III, 317–412; S. Van Valkenburg, "Agricultural Regions of Asia. Part IV—India," *Economic Geography*, April 1933, IX, 109–35; and *Report on the Marketing of Wheat in India* (Delhi, 1937).

[2] Bennett, *op. cit.*, p. 79.

age. Not infrequently the monsoon rains are so light or retreat so early that unirrigated ground is too dry to germinate seed when the time comes to sow, and seeding will be curtailed. The great variability of acreage sown in the southern part of the wheat belt, where irrigation is least practiced, is illustrated in Chart 7. Since this area is also the area of relatively low level of yield, a large reduction in its acreage has a tendency to raise the average level of yield in India as a whole, and conversely.

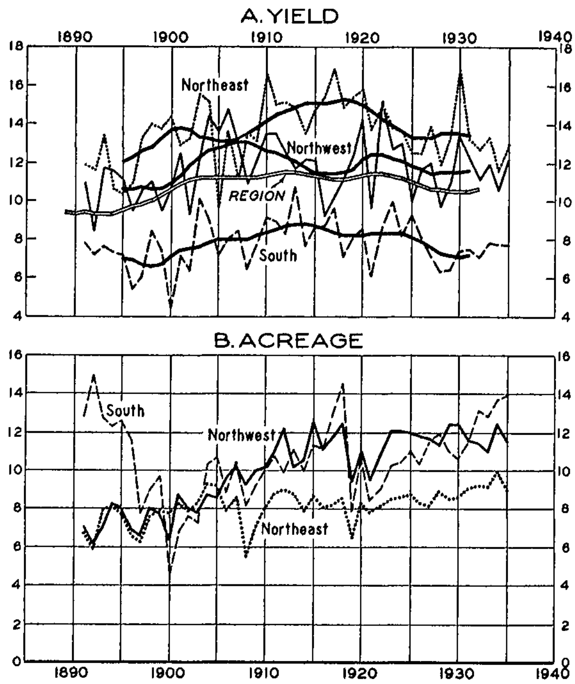
The course of the moving average of all-Indian yield (Chart 2, p. 225, and hollow line in Chart 7) was upward between 1895 and 1903, and then moved about horizontally until 1922 and declined thereafter. The level in 1895[1] was 9.5 bushels; in 1913, 11.5 bushels; in 1930, 10.5 bushels. These are small changes in absolute terms but more substantial in percentage terms.

The principal influences that have determined the slope and conformation of this trend were probably the weather, internal shift of acreage, change in the proportion of wheat acreage irrigated, and introduction of new varieties. Perhaps statistical inaccuracies were also significant, but we find no good basis for appraising their effect.[2] The first three of these influences seem to be closely interrelated and in some degree offsetting in their effect upon yield. Deficient summer rains may cause curtailment of the acreage sown on unirrigated land where yields are low. These deficient rains tend on the one hand to lower yield on such unirrigated land as is sown to wheat and (through curtailment of stored water supply) on irrigated land also; on the other hand, they tend to increase the weighted average yield by enlarging the fraction of the wheat acreage sown on the higher-yielding irrigated land.

We are inclined to regard the increase in the level of Indian yield between 1895 and 1913 largely as reflection of uncommonly poor average weather conditions in the early period and perhaps unusually favorable conditions in

CHART 7.—TRENDS OF WHEAT YIELD PER SOWN ACRE IN SUBDIVISIONS OF INDIA, AND YIELD AND ACREAGE ANNUALLY, SO FAR AS AVAILABLE FROM 1885*

(Bushels per acre; million acres)



* Subdivisions defined in accompanying text. The hollow line represents trend of yield in India as a whole, as in Chart 2.

the later period—conditions which themselves caused a geographical shift of acreage moderately favorable to increase of yield.[3] But some part of this increase probably represented persistent trend-increase in the proportion of wheat acreage under irrigation, as well as some spread of improved varieties. Geographical shift of acreage, however, could not have been very important in the decline of yield from 11.5 bushels around 1913 to 10.5 around 1930, for there was little change

[1] It seems advisable not to depend upon statistics prior to those of 1891 (see Bennett, *op. cit.*, p. 79); and the weighted nine-year moving average centering in 1895 is the earliest that can be drawn from statistics beginning with 1891.

[2] An official report, commenting on statistics showing decline of average yield per acre between 1910–14 and recent years ending with 1934–35, remarks that "whether this reduction is real or only apparent depends mainly on the accuracy of the official estimates . . . ." (*Report on the Marketing of Wheat in India, op. cit.*, p. 13).

[3] The sharp upturn of Indian yield between 1895 and 1903 rests heavily upon the drastic reduction of acreage in the southern part of the wheat belt between 1895 and 1900 without recovery to the earlier level by 1907.

between those periods.[1] Nor is there evidence of decline in the proportion of wheat under irrigation, though increase in this fraction was less marked from 1913 to 1930 than from 1895 to 1913. The later period, moreover, was one that witnessed adoption of new high-yielding varieties on a substantial scale.[2] The decline of yield from 1913 to 1930 thus must reflect either changing weather conditions or progressive decline in soil fertility—assuming, of course, the substantial accuracy of the statistics.

Without adequate examination of the facts, we hazard the guess that weather conditions over nine-year periods centering in 1895 and 1930 were rather unfavorable, and in 1913 rather favorable. The trend of yield "corrected" for weather influence might therefore rise slightly throughout its course, perhaps a little more rapidly between 1895 and 1913 than between 1913 and 1930. Of the three principal trend-raising influences — shift of acreage, change in the proportion irrigated, and introduction of improved varieties—the first two seem to have been more strongly operative in the earlier period. If this interpretation is acceptable, it follows that man-made changes in the wheat plant and its environment have roughly sufficed to overcome the persistent drain upon the soil. Like trends of yield in France and Eastern North America but unlike the trends in the other five regions thus far considered, Indian yield per acre has been assisted by the internal shifts of wheat acreage that occurred between the 'nineties and the early 'thirties.

II. STABLE AND DECLINING TRENDS

Southeastern Europe, the Western Mediterranean region, and three regions in the great central plain of North America show trends of yield that have been classified as stable or declining (Chart 3, p. 225). Declining tendencies, however, were less in evidence in the first half of the period than in the second. "Accidental" influences (inaccuracies of statistics and the succession of seasons) somewhat masked declining tendencies before the war; and in this period expansion of acreage in the central plains of North America was in considerable degree toward relatively high-yield territory.

"Normal" yields — yields reflecting influences other than accidental—in Southeastern Europe and the Western Mediterranean region have been at about the same level in recent years as they were just before the war. The principal factor adverse to yields was expansion of wheat acreage to relatively low-yielding territory; this was approximately offset by improvement in wheat varieties and some degree of improvement in agricultural technique (rotations, use of fertilizer, mechanical methods) most clearly in evidence on the moister peripheries of both regions. In the eastern part of Southeastern Europe, however, agricultural technique is probably at a lower level today than it was before the war.

The recorded levels of weighted average yield in the Hard Winter and Spring Wheat regions of the United States and the Prairie Provinces of Canada were lower in 1933 than in 1913 by 3.6, 5.8, and 7.6 bushels respectively (in percentages, 29, 47, and 39). In substantial degree these declines are accidental, due to ravages of drought and rust in the years especially since 1933; but accidental developments by no means account for all of the decline. In general, these regions have witnessed an extraordinary expansion of wheat acreage into the normally dry and low-yielding part of the great central plain. The climate circumscribes rather narrowly the crops that can be grown as well as the use of fertilizer. Hence rotations must consist principally of small grains and fallow; and such rotations, practically without fertilizer, are apparently inadequate at once to maintain soil fertility and to restrain weed growth. There has been general improvement in wheat

[1] The very low acreage in the south during 1919–22, however, helped to form the slight bulge of yield centering in 1921 and 1922.

[2] Recently wheats classed as "improved" were grown on about 6.5 million acres, nearly a fifth of the total; see *Report on the Marketing of Wheat in India, op. cit.*, p. 23. The selection and distribution of improved varieties was in its infancy just before the war.

varieties and in techniques of plowing, sowing, and management of fallow. But only in the moister eastern fringe of the central plain has recourse been feasible to the powerful yield-improving instruments of humid regions—fertilizers combined with rotations including sod crops, legumes, and intertilled crops. The generally narrow scope for technical advance, coupled with the extremely rapid expansion of wheat acreage into dry territory, has lowered the level of wheat yield in these three regions more than in any other.

Southeastern Europe

Southeastern Europe includes territory now lying within the boundaries of Greece, Bulgaria, Rumania, Yugoslavia, Hungary, and the eastern provinces of Czechoslovakia just to the north of Hungary. In this more or less triangular territory with its southern point (Greece) on the Mediterranean, one side along the Adriatic, and the other along the Aegean and Black Seas, the climate of the wheat belt is predominantly continental in type.[1] Mediterranean influences are moderated by the mountain ranges along the Adriatic, Atlantic influences by the Alps. The wheat belt—in general coincident with the agricultural belt—lies inland from these mountains, largely in the basin of the Danube, partly on the westward extension of the Russian steppe and along the littoral of the Black and Aegean seas. Within this belt the rainfall increases from about 15 inches in the east, on the shores of the Black Sea, to about 30 inches in western Hungary. Wheat yields per acre, which fluctuate rather widely from year to year, tend broadly to follow this progression. The principal seasonal peak of rainfall comes in May–July, a secondary peak in October. The winters are cold enough to injure winter wheat more or less every year; but abandonment is seldom heavy and spring wheat is little grown except in the northeast adjacent to Russia.

Like annual rainfall and wheat yield, agricultural technique tends broadly to improve from east to west. In the east and south (and even in northeastern Hungary) the ancient three-field system of crop rotation of fallow, winter wheat or rye, oats or barley, is still followed in some localities. Much more common in the southern and larger part of the region, however, is a two-field system, corn followed by winter wheat. In places this is extended to include a year of fallow or a year of spring-sown barley or oats; and in places winter rye may displace winter wheat or share a year with it. The rotations seldom include much besides the grains, and only in the western fringe do root crops and legumes attain some prominence in crop rotations. Draft animals and some meat animals feed principally from permanent pasture, so that manure is not much used on the fields. Commercial fertilizers are rarely used except in the extreme west, where also the rotations are superior and there is some development of an intensive livestock industry.

The regional wheat acreage (Chart 3, p. 225) increased from about 15 million acres in 1885 to about 22 million just before the war; then fell sharply to 1919 and thereafter rose, reaching 24 million acres in 1936. This expansion coincided with growth of the total arable acreage, mainly at the expense of pasture but partly from reclaimed swamps; and it accompanied growth of the area in corn and decline of the area in rye and in fallow. Some of the former pasture was good land, as was that reclaimed. But to some extent, particularly in the southern stretches of the belt, the wheat area expanded to poorer land, and displacement of rye and fallow by wheat could not have been favorable to wheat yield per acre.

Except for prominent depressions centering in 1898 and 1918–20, regional average yields per acre have moved horizontally at a level of about 16 bushels. The first of these depressions probably reflected merely a series of bad years, especially 1897 and 1899; the second reflected bad weather, disruption of farming operations during and following the war, and probably inaccuracy of statistics.

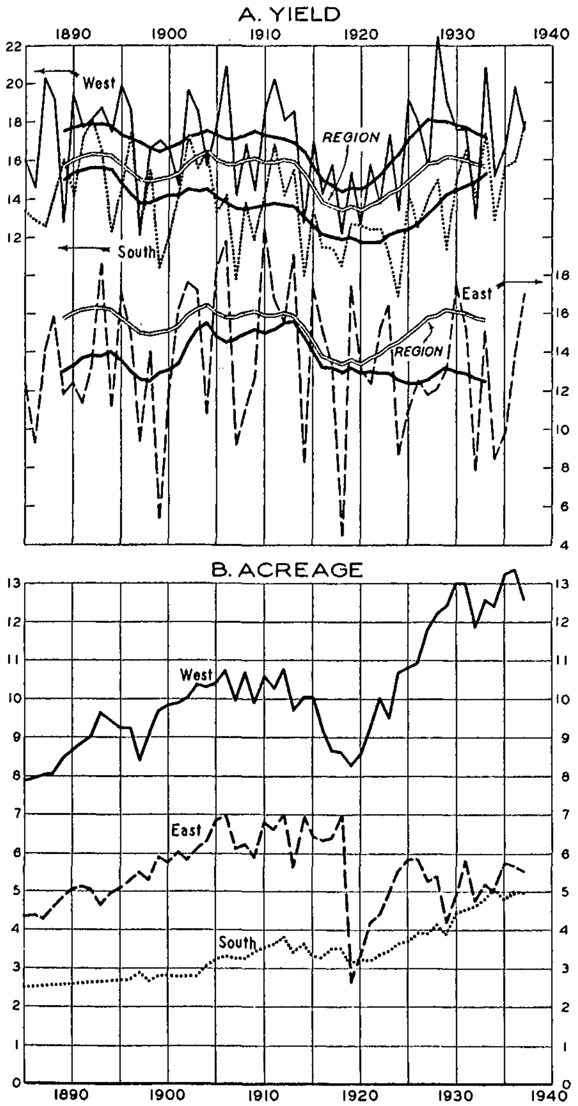
The regional trend in prewar years, stable except for the dip during the late 'nineties, represented diverse trends in different parts of the region, as indicated in Chart 8. Be-

[1] Description of this region and analysis of yield trend rest heavily upon V. P. Timoshenko, "The Danube Basin as a Producer and Exporter of Wheat," Wheat Studies, March 1930, VI, No. 5.

tween 1890 and 1910 there was a slight decline in the western part of the region (the prewar kingdom of Hungary, Bosnia-Herze-

CHART 8.—TRENDS OF WHEAT YIELD PER HARVESTED ACRE IN SUBDIVISIONS OF SOUTHEASTERN EUROPE, AND YIELD AND ACREAGE ANNUALLY, FROM 1885*

(Bushels per acre; million acres)



* Subdivisions defined in accompanying text. The hollow lines represent trend of yield in Southeastern Europe as a whole, as in Chart 3.

govina, and Serbia); a substantial decline in the southern part (Bulgaria and Greece); but a substantial increase in the eastern part (old Rumania and Russian Bessarabia). The decline in the southern part seems explicable in terms of encroachment on fallow, extension of wheat to drier hilly land, and continued cultivation by a peasant population on small farms where improved techniques could be introduced only with great difficulty and very slowly. The increase in the eastern part seems explicable by the fact that prewar wheat production was largely on big estates which progressively introduced improved machinery, new varieties, and better rotations. The slight decline in the western part probably represented the effects of expansion of wheat acreage on sandy soils formerly in rye and on drier eastern soils of the great central plain of old Hungary and of hilly pastures in the south. This seems to have overcome the favorable effects of substantial progress in agricultural technique in the western part of old Hungary, where rotations improved, use of manure and commercial fertilizers became increasingly common, new varieties were adopted, and improved machinery was introduced particularly on the rather numerous large estates. In the region as a whole, the rise of yield in the eastern part sufficed to offset decline of yield elsewhere, so that the prewar regional trend changed little.

The regional average level of yield in 1930 was practically the same as in 1910, about 16 bushels. This lack of change was again the net result of diverse developments in different parts of the region. In the western and southern parts, both the level of yield and the level of acreage were higher in 1930 than in 1910. In these two parts, improved agricultural technique more than offset the unfavorable effects of spread of wheat acreage to inferior land. The higher postwar level in the southern part, however, represents also change of boundaries and of statistical methods.[1]

The decline of yield in the eastern part (old Rumania and Bessarabia) was of substantial

[1] Postwar Bulgaria excludes the Dobrogea, a relatively low-yield area that was partly included in prewar Bulgaria. If this district were included throughout the period, the postwar level of yield in the "southern part" that includes Bulgaria would be a little lower than Chart 8 indicates. Recent changes in Greek methods of crop estimation suggest either that prewar yields were here appraised too low or that the late postwar yields are too high; in any event the effect is to make the 1930 level of yield in the "southern part" compare too favorably with the 1910 level.

magnitude—from 15.0 bushels in 1910 to 13.0 bushels in 1930. This is all the more remarkable because decline in yield coincided with decline in acreage; in all other regions we have found decline of acreage associated with increase of yield. Changes in boundaries were such as to explain some small part of these reductions, for the postwar data include the low-yielding Dobrogea district while the prewar data do not. The principal cause of decline in yield, however, appears to have been deterioration of agricultural technique. In this eastern part of Southeastern Europe, agrarian "reform" was drastic, in effect transforming the countryside from one with much of the farming area in large, rather well-managed estates to one with practically all of the farming area in tiny peasant farms. Rotations, seed, and implements all suffered with the change that came at the close of the war, and shortage of capital among peasant proprietors restrained improvement of techniques subsequently. The peasants tended to expand the acreage of their food crop, corn, at the expense of their cash crop, wheat; and perhaps this shift involved some retreat of wheat to inferior land.

The major reasons why the level of yield per acre in Southeastern Europe remained practically unchanged between 1890 and 1930 were somewhat as follows. Statistical inaccuracies caused the course of the moving averages to rise, but only slightly. The succession of seasons seems to have affected these particular averages only a little. Internal shifts of acreage within each of the three parts of the region were probably unfavorable to increase of yield; but shifts of acreage from the low-yielding south and east to the higher-yielding west were favorable. Changes in agricultural technique were favorable to yield in the west and south, though slow-moving in both; but probably unfavorable in the east. Where improvement of technique occurred, it took mainly the form of better seed and better machinery, and improvements in rotations or fertilization were minor.

Western Mediterranean

Wheat in the Western Mediterranean region (Spain, Portugal, Morocco, Algeria, and Tunis) is at once a very old crop and a pioneer crop. This was grain-producing territory in the days of ancient Rome. But only recently have the interior parts of French North Africa come under French control, and particularly in Morocco, Tunis, and the interior plateau of Algeria, recent expansion of wheat acreage in some degree represents colonization of a type that involves purchase of land from natives with control of the number and location of colonists.

The terrain is cut up by mountain ridges, and the wheat area lies partly on coastal plains, partly in the bottoms and adjacent rolling hills of river valleys sloping down from mountains and debouching into the Mediterranean or the Atlantic, and partly on inter-mountain plateaus of the interior. Under these circumstances the climates and soils of the wheat belt are locally rather diverse. Yet most of the belt receives only 15–25 inches of rainfall annually; and most of it lies in a Mediterranean climate of mild or fairly mild winters and hot dry summers. Not much wheat is grown in the northwestern corner of the Iberian Peninsula, where Atlantic influences are stronger and the rainfall heavier and more evenly distributed throughout the year.

Yields per acre in northern Africa tend to increase both from south to north and from east to west; they are highest on the coast of Algeria, and in Morocco where exposure to Atlantic influence is greatest. In the Iberian Peninsula yields are definitely highest in the north, but lower in the central plateaus than on the coasts. Except in the north of the Western Mediterranean region, the general level of yield is low, falling to less than 7 bushels in Tunis. This reflects in some small degree a short growing season (in many sections wheat may not be sown until December or January and is harvested in May or early June), but primarily a low level of cultural methods and chronic damage from heat and drought in the spring.[1] Practically all wheat is sown in the late autumn or early winter, but most of it has a spring habit of growth. Durum is widely produced, particularly by

[1] G. Azzi, *Le climat du blé dans le monde* (Rome, 1930), especially pp. 231, 937.

native cultivators in northern Africa, but also in Spain and Portugal; the other wheats range from soft to semi-hard and include both red and white varieties.

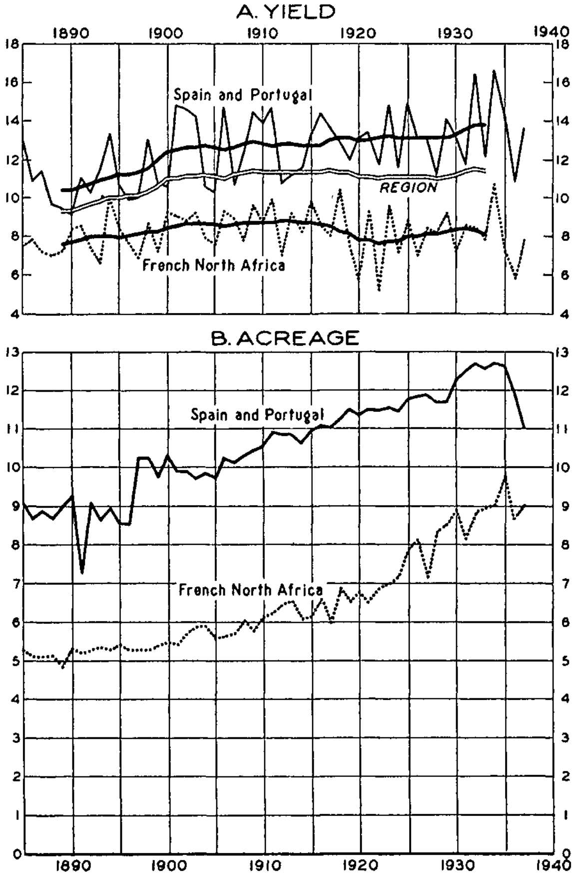
In general, the agriculture of this region involves use of land for pasture, for tree crops and vines, for fallow, and for cereals. Slightly over half of the arable land has been devoted to cereals in recent years, two-fifths of it to fallow, and less than a tenth to all other crops. Of the cereal acreage, roughly 50 per cent was in wheat, over 30 per cent in barley, and less than 20 per cent in other cereals.

The importance of fallow is obvious, and rotations rather widely typical are fallow for one or several years, followed by a cereal—likely to be wheat since wheat is the major cereal—for one or several years.[1] Some of the fallow is clean-cultivated, designed to conserve moisture; but much more of it is merely idle land used for pasture while in stubble and after it has covered itself with native weeds and grasses.[2] Wild legumes are common on this sort of fallow, and may help to maintain soil fertility. On the moist Mediterranean coast of northern Africa and in the northwestern part of the Iberian Peninsula, rotations without much fallow emerge, together with use of fertilizer and generally improved technique. But little wheat is grown here, and in the bulk of the wheat-growing belt of the Western Mediterranean region, neither scientific rotations, clean-cultivated fallow, fertilization, nor other advanced methods are typical. Some wheat is grown under irrigation, especially in Spain; but the fraction is small.[3]

The regional trend of wheat yield per acre, as pictured in Chart 3 (p. 225) and Chart 9, moved with little change at a level of 11 to

CHART 9.—TRENDS OF WHEAT YIELD PER HARVESTED ACRE IN SUBDIVISIONS OF THE WESTERN MEDITERRANEAN REGION, AND YIELD AND ACREAGE ANNUALLY, FROM 1885*

(Bushels per acre; million acres)



* Subdivisions defined in accompanying text. The hollow line represents trend of yield in the Western Mediterranean region as a whole, as in Chart 3.

11.5 bushels after 1900. Prior to that date the trend was apparently rising; but the basic statistics seem unreliable and the indicated early advance of yield may well be spurious and hence not worth discussing.[4] There appears to be reasonable probability that the trends after about 1900, in the region as a whole and in its two principal parts, provide credible approximations to the facts, though

[1] "L'assolement biennial: une année de culture et une de jachère préparée, tend à se généraliser dans l'Afrique du Nord." Mm. Lévy and Chollet, "L'intensification de la culture du blé en Algérie au point de vue européen et indigène," *Semaine national du blé* (Paris, 1923), p. 498. This publication contains other articles that illuminate the position of wheat in northern Africa. See also M. M. Knight, "Water and the Course of Empire in North Africa," *Quarterly Journal of Economics*, November 1928, XLIII, 44–93.

[2] T. H. Kearney and T. H. Means, *Agricultural Explorations in Algeria* (U.S. Dept. Agr., Bur. Plant Indus. Bull. 80, August 1905), p. 77.

[3] In Spain, the proportion of the wheat acreage irrigated was 5.6 per cent in 1901–05 and 5.2 per cent in 1930–34, according to data in J. M. Morgades, *Anuaria estadístico de cereales* (Barcelona, 1935), p. 7.

[4] Bennett, *op. cit.*, p. 79.

the literature concerning wheat in this region is decidedly meager.[1]

The slope and conformation of the trends after 1905 seem to have been affected little by the succession of good and bad seasons. The main effects of weather were perhaps to cause moderate depression of trend just after the war, as a result of particularly bad seasons in northern Africa in 1920 and 1922; and to cause upturn after 1929, as a result of particularly good seasons in the Iberian Peninsula in 1932 and 1934, the latter year being notably favorable in northern Africa also. On the whole, the change in levels of average yield between periods centering in 1905 and 1930 respectively thus seem attributable to other influences than statistical inaccuracies or weather, and initial levels of yield cannot be significant here.

The wheat acreage increased in the region as a whole and in both of its major parts. So far as we can infer from fragmentary statistics, the growth of wheat acreage in Spain has represented mainly encroachment on fallow and some substitution of wheat for rye. Reduction of the fallow, which was largely of the uncultivated type, may represent improvement of crop rotations that favorably affected trend of yield; at least there was increase in the area sown to grass, legumes, and root crops. If use of manure, commercial fertilizer, improved seed, or superior machines grew concurrently, we have been unable to find specific evidence of it; but we are disposed to assume that there was a small tendency for yields to be affected favorably in these ways.

In northern Africa, increase of wheat acreage was apparently mainly the result of extending arable cultivation into unsettled territory or nomadic pasture. The wheat acreage grew more in Tunis and Morocco than in the older colony, Algeria.[2] In each colony taken separately, the expansion was toward drier and lower-yielding land. Hence, despite the fact that expansion was greatest in Morocco where yields average highest, we are inclined to explain the slight decline of northern African yields in terms of acreage expansion. This, together with continued drafts upon soil fertility, apparently sufficed to more than offset other developments favorable to wheat yield.

These developments were associated with relatively greater growth of European than of native cultivation. By 1930, Europeans were cultivating a substantially larger fraction of the cereal acreage than in 1905; and since Europeans have always obtained much higher yields than the natives,[3] yields averaged for both types of culture tend to increase as the fraction of the acreage cultivated by Europeans increases. The Europeans apparently achieve the higher yields mainly by plowing their fallow deeper and keeping it cleanly cultivated so as to conserve moisture (operations to which superior plows contribute heavily), but partly by sowing with drills instead of broadcast and by using better varieties.[4] There has also been some tendency for native farmers to adopt European methods. Another factor may have been gradual enlargement of the proportion of the wheat area sown to bread wheat, which is said to resist heat and drought better than durum and thus to give higher yields.[5]

The changing geographical distribution of wheat acreage seems unimportant in its specific effect on trend of average yield in the Iberian Peninsula, but in northern Africa probably adverse. In the Western Mediterranean region as a whole it was also adverse, for a larger proportion of the regional acre-

[1] The principal uncertainty is with reference to Spain. The official Spanish statistics here used indicate between 1905 and 1930 an increase of average yield from 12.8 to 13.6 bushels, whereas the statistics of the newspaper *El Norte de Castilla*, running throughout at a lower level, indicate a larger increase, from 11.2 to 12.6 bushels. But both series point toward increase rather than decline.

[2] Between three-year periods centering respectively in 1905 and 1930, the wheat acreage increased by about 1.58 million acres in Morocco, 0.83 million in Tunis, and 0.44 million in Algeria.

[3] The extent of this disparity is variable, but may attain 30 to 50 per cent; it appears in both durum and bread wheats. See V. Demontès, *Renseignements sur l'Algérie économique* (Paris, 1922), p. 73.

[4] See F. Boeuf, "Amélioration de la production des céréales en Tunisie," International Institute of Agriculture, *International Review of Agriculture*, July 1935.

[5] Azzi, *op. cit.*, p. 931. This seems contrary to experience in many parts of the world where durum is grown.

age lay in relatively low-yielding French North Africa in 1930 than in 1905. Maintenance of the regional level of yield therefore seems to have been due largely to improvement of rotations in the Iberian Peninsula, wider use of the cultivated fallow in French North Africa, and gradually spreading use of improved machinery and wheat varieties in both sections.

Our impression is that yields could be increased substantially in the Western Mediterranean region without great capital outlay, through better management of the fallow generally and moderate applications of fertilizer in some districts where the moisture is adequate.[1] It is conceivable also that partitioning of large estates in Spain, if continued or carried further, would have the effect of increasing wheat yields, not of reducing them as in Rumania (see p. 240).

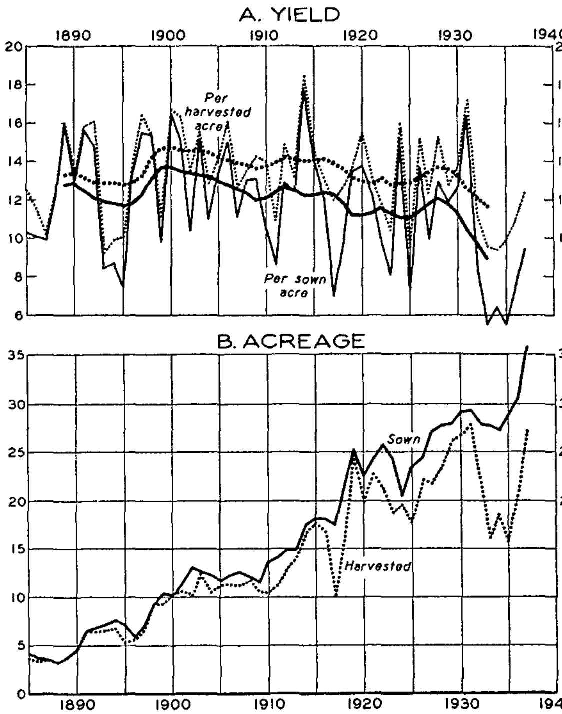
UNITED STATES HARD WINTER

In terms of wheat acreage, the United States Hard Winter region follows India as the largest of the fourteen regions considered in this study. It is also the largest surplus-producing region of the United States. Chart 10 gives a contrast of wheat area sown[2] and harvested, and yield per acre sown and harvested, in this region. The sown acreage rose to nearly 36 million acres in 1937—an acreage larger than was sown in any region in any year except in India in 1934 (Chart 2, p. 225). Abandonment of sown acreage is very heavy in some years and was particularly so in 1932–37; hence sown acreage indicates better than harvested the strong tendency to expand the wheat area characteristic of the region since 1885.[3]

In prewar years, the Hard Winter region

CHART 10.—TRENDS OF HARVESTED AND APPROXIMATE SOWN YIELDS PER ACRE IN THE UNITED STATES HARD WINTER REGION, AND YIELDS AND ACREAGE ANNUALLY, FROM 1885*

(Bushels per acre; million acres)



* States of Nebraska, Kansas, Oklahoma, Texas, Wyoming, Colorado, and New Mexico. Area harvested compiled from official statistics of the U.S. Department of Agriculture, *Revised Estimates of Wheat Acreage, Yield and Production, 1886–1934* (Washington, mimeographed, September 1934; reissued May 1937), and subsequent *Crop Reports*. Area sown: from 1919, *ibid.;* 1909–18, *ibid.*, winter wheat sown plus spring wheat harvested; 1901–08, harvested acreage from *ibid.*, adjusted to approximate acreage sown by reference to percentages of winter-wheat acreage abandoned in Nebraska, Kansas, Oklahoma, and Texas, as given in U.S. Department of Agriculture, *Wheat and Rye Statistics* (Stat. Bull. 12, January 1926), p. 12; and 1885–1900, harvested acreage from *Revised Estimates . . . .* except that for Kansas we use sown acreage as estimated in *Biennial Reports* of the Kansas State Board of Agriculture. Production estimates used in calculating yield per acre are throughout from the *Revised Estimates . . . .*

was a true pioneer area, characterized by large and persistent increase of the amount of land in farms. Expansion of wheat acreage then reflected in large degree the progress

[1] Thus of Portugal it is said, "The results obtained with nitrogen have been so striking, and so well defined that the lack only of this necessary element has been proved to be a limiting factor in fertility." A. H. W. King, *Economic Conditions in Portugal* (Great Britain, Dept. of Overseas Trade, Report 528, July 1932), p. 46.

[2] As the footnote to Chart 10 suggests, the estimates of area sown and yield per acre sown in this region cannot be based upon continuous official series. The sown-acreage series presented in the chart represent our approximations, which we regard as reasonably dependable and as better suited to analysis of the situation in this region than continuous official series of area and yield per acre harvested (see p. 224).

[3] On the incentives to expand wheat acreage in this region, see A. E. Taylor, "The Contractility of Wheat Acreage in the United States," WHEAT STUDIES, February 1930, VI, 159–64.

of settlement. Since 1920 there has been much slower growth of new settlement and of land in farms, and the continued expansion of wheat acreage has represented new settlement in smaller degree, and in larger degree encroachment of arable land on pasture especially in the dry western reaches, together with some slight displacement of corn by wheat farther east.[1] Both developments have been stimulated by the advent, improvement, cheapening, and wider use of the tractor and the combined harvester-thresher, with their tendency to reduce costs of production especially of small grains. The topography and the large farms of the western part of the region favor the use of such machinery.

Because of the heavy winterkilling of wheat in the Hard Winter region and a tendency for this to increase with expansion of acreage to drier land, yield of wheat per sown acre falls substantially below yield per harvested acre and has shown a stronger tendency to decline (upper tier, Chart 10). This region, the twelfth in order of discussion, is the first of three wherein a long-continued downward drift of yield per acre is clearly perceptible. Since these regions are important ones with reference to acreage and exceptional ones with reference to trend of yield, we discuss the underlying physical characteristics at greater length.

The region lies within two tiers of states running from north to south: on the east, Nebraska, Kansas, Oklahoma, and Texas; on the west, Wyoming, Colorado, and New Mexico. Of these three western states, the Rocky Mountains occupy all but about the eastern fourth. Semi-desert prevails in a substantial part of southwestern Texas, extending into southeastern New Mexico. In these mountain and semi-desert regions there is little agricultural activity aside from grazing.

Eastward from these mountainous and arid boundaries extends a vast and almost treeless plain, sloping toward the Mississippi River and the Gulf of Mexico; and here lies the land devoted to crop production. Very little wheat is grown, however, in the southeastern third of this plain, including the eastern half of Oklahoma and all of Texas except the panhandle and a strip of territory just south of the border of central Oklahoma. The bulk of the productive agricultural area of Texas and eastern Oklahoma lies in the cotton belt.

Throughout the wheat belt the average annual rainfall in general diminishes from east to west, with some slight tendency to diminish from south to north also. The range is from about 14 inches at the western extremity (in Colorado and Wyoming) to 42 inches (in extreme southeastern Kansas); but only a small fraction of the wheat acreage lies east of the 35-inch isohyet that passes from northeastern Kansas down through east-central Oklahoma. Rainfall averages less than 25 inches throughout that part of the wheat belt lying in Wyoming, Colorado, New Mexico, the panhandles of Texas and Oklahoma, the western half of Kansas, and the western two-thirds of Nebraska. The 25-inch isohyet corresponds very roughly with the eastern and moister boundary of the so-called "Great Plains," though definitions of this area differ.[2] The area that has come to be called "dust bowl" since the droughts of 1933 and 1934 lies in the southern part of the Great Plains.

The climate of the wheat belt of the Hard Winter region is continental in type, with cold winters, hot summers, and a summer

[1] See especially H. Hedges and F. F. Elliott, *Types of Farming in Nebraska* (Nebraska Agr. Exp. Sta. Bull. 244, May 1930), pp. 34–37; J. A. Hodges, F. F. Elliott, and W. E. Grimes, *Types of Farming in Kansas* (Kansas Agr. Exp. Sta. Bull. 251, August 1930), pp. 43–46; J. O. Ellsworth and F. F. Elliott, *Types-of-Farming in Oklahoma* (Oklahoma Agr. Exp. Sta. Bull. 181, June 1929), pp. 22–27; C. A. Bonnen and F. F. Elliott, *Type-of-Farming Areas in Texas* (Texas Agr. Exp. Sta. Bull. 427, May 1931), pp. 37–38.

[2] The western boundary is taken by all writers as the eastern foothills of the Rocky Mountains. Thornthwaite places the eastern boundary about on the 25-inch rainfall isohyet in Texas and Oklahoma, but farther west in Kansas and Nebraska—paralleling approximately the dividing line between natural vegetation of short grass on the west, tall grass on the east. The Great Plains Committee places the eastern boundary east of the 25-inch isohyet, approximately paralleling the western boundary of humid soils (pedalfers). See C. W. Thornthwaite, "The Great Plains" (chapter v in C. Goodrich *et al.*, *Migration and Economic Opportunity, Philadelphia*, 1936); and *The Future of the Great Plains: Report of the Great Plains Committee* (Washington, 1936). However defined, the Great Plains extend north of the Hard Winter region here under consideration, into the Spring Wheat region of the United States and the Prairie Provinces of Canada.

maximum of seasonal rainfall. The length of the frost-free or growing season diminishes from southeast to northwest, reflecting not only the usual decline of temperature from north to south but also a decline due to the rising elevation from east to west. In northwestern Nebraska and northeastern Wyoming the frost-free season is less than 120 days; whereas in central Oklahoma and the panhandle of Texas it approaches 200 days.[1] The soils are mostly deep and fertile, the topography flat or gently rolling and well suited to large-scale cultivation by machine methods. Certain districts, however, are unsuitable for much arable cultivation and are devoted mainly to grazing; among these, notable ones are the sand hills of north-central Nebraska, the Flint Hills of southeastern Kansas, and the "breaks" along the Canadian River traversing the panhandle of Texas. Winter wheat greatly predominates throughout the region, though spring wheat is grown especially in Wyoming (except the southeast), in northwestern Nebraska, and in irrigated districts of all four of the westernmost states.[2] The winter wheat is of the hard red type except in the eastern parts of Kansas, Oklahoma, and Texas where soft red wheats predominate.

Crop rotations[3] are not stabilized in most places. In the eastern parts of Nebraska and Kansas, the older-settled and moister regions, rotations resembling those in the corn belt farther east are common—often corn for two years, followed by oats or winter wheat, followed by leguminous hay or another year of small grain; wheat occupies only a moderate or a small fraction of the arable acreage in this part of the region. In the southeast, cotton and corn are dominant crops and wheat is insignificant. Farther west, in central Kansas and north-central Oklahoma, wheat becomes dominant; it often occupies more than 70 per cent of the arable land and on many fields wheat follows wheat for a series of years occasionally interrupted by corn, a small grain, or alfalfa that is left to occupy a field (usually small in relation to the arable land of a farm) for several years in succession. Unplowed pasture is still important in this district.

The pasture occupies an increasing fraction of the land in farms—50 per cent or more—as one moves westward into the panhandles of Texas and Oklahoma, or to New Mexico, western Kansas, Colorado, western Nebraska, and Wyoming. In the southern half of this western district, the principal crops are wheat and grain sorghums, and more or less fallow appears. Rotations seldom involve the simple system of fallow and wheat alternately, so common in Australia and the Pacific Northwest; for, although wheat gains in yield from following fallow, in wide areas it does not gain enough to offset the profits of continuous wheat growing, or of fallow one year and wheat several years, or of combinations involving grain sorghums for several years, then fallow, then wheat for several years. In the northern half of the western district the position and use of the fallow are similar, but corn rather than sorghum is the principal clean-cultivated crop. Corn in the northern half generally occupies a smaller fraction of the arable land than does sorghum in the south, while wheat occupies a larger fraction.

Except in the eastern stretches of the Hard Winter region, there is accordingly a good deal of practically continuous wheat cultivation. On many farms, the great bulk of the acreage not in pasture is sown to winter wheat year after year. Moreover, except in the eastern stretches the use of fertilizer is so uncommon as to be negligible;[4] commercial fertilizers are little used even in the east, and farther west even barnyard manure goes mainly to pasture rather than to the arable land, partly because effective use of it is diffi-

[1] See map in O. E. Baker, *A Graphic Summary of Physical Features and Land Utilization in the United States* (U.S. Dept. Agr. Misc. Pub. 260, May 1937), p. 7.

[2] In Colorado the wheat acreage under irrigation is larger than in any of the other states. But even here the percentage irrigated is small, only about 11 per cent in 1929. See B. Hunter *et al.*, *Type of Farming Areas in Colorado* (Colorado Agr. Exp. Sta. Bull. 418, September 1935), p. 35. The percentage varies from year to year.

[3] See the type-of-farming studies cited in the preceding footnotes; also J. S. Cole and S. C. Salmon, in *Yearbook of Agriculture, 1933*, pp. 154–55.

[4] A sample inquiry in 1936 indicated an average cost of fertilizer and manure applied to wheat in Nebraska, Kansas, Colorado, Texas, and Oklahoma of only 14 cents per acre; see *Crops and Markets*, December 1937, p. 308.

cult.[1] There is little indication of substantial improvement of either crop rotations or use of fertilizers in most of the Hard Winter region during the past half a century, though the more humid northeastern portion seems to be exceptional.

As appears from Chart 10 (p. 243) yields of wheat per sown acre in the Hard Winter region vary widely from year to year, ranging from as little as 5.5 bushels to as much as 17.7 bushels. Approximately this or a larger degree of variability exists also in the different parts of the region, as Chart 11 indicates. This chart shows approximate annual yields per sown acre (with weighted nine-year moving averages) and annual acreage sown in (*a*) the "Northeast"—the eastern half of Kansas and the whole of Nebraska, in the main the older-settled part of the region where rainfall is relatively abundant and temperatures relatively moderate; (*b*) the "Northwest"—the western half of Kansas, all of Colorado, and all of Wyoming, a more recently developed area in general drier and colder; and (*c*) the "South"—all of Texas, Oklahoma, and New Mexico, also a recently developed region in the main and one wherein the bulk of the wheat acreage now lies in territory warmer than the "Northwest" but about equally dry.[2] Yields per sown acre in the region as a whole and in its three parts not infrequently fall to surprisingly low levels. Regional yields have been less than 9 bushels in 9 of the 27 years between 1910 and 1936, a poorer record than in any of the fourteen wheat-producing regions here considered except the United States Spring Wheat region. Not even Australia and India, with lower average yields, have experienced so many years of low yields since 1910.

The variability of yields is associated with wide variability of annual rainfall, though with other factors as well. Ordinarily, drought is the main cause of low yields. If rainfall is deficient in the summer preceding the sowing season (typically September – October), the seed may germinate badly and the plants may fail to establish themselves well enough to resist cold spells or dry spells in the winter and strong dry winds in the early spring—seasons when precipitation is normally light—and abandonment may run very high.[3] Under such circumstances even normal or heavy rainfall in the late spring and early summer of the year when the wheat is harvested is not likely to result in good yields per sown acre. On the other hand, a favorable level of accumulated soil moisture in the autumn goes far

[1] It is stated with regard to central Kansas that "Excessive applications [of barnyard manure] may cause lodging during a wet year and burning during a dry year"; and with regard to western Kansas that ". . . . manure has for the most part failed to give any marked increases in yield except on soils that have been eroded. In some cases a loss in yield has resulted from too heavy an application." S. C. Salmon and R. I. Throckmorton, *Wheat Production in Kansas* (Kansas Agr. Exp. Sta. Bull. 248, July 1929), pp. 17–18.

[2] This subdivision of the Hard Winter region has necessarily been based upon heterogeneous series of crop statistics. The data for the states of Nebraska in the "Northeast," Colorado and Wyoming in the "Northwest," and Oklahoma, Texas, and New Mexico in the "South" are those of the U.S. Department of Agriculture—basically, production of all wheat as published; sown areas of winter and spring wheat from 1919, as published; approximate sown areas 1909–18 derived from published statistics of winter-wheat area sown plus spring-wheat area harvested; approximate sown areas 1901–08 derived from published statistics of spring-wheat area harvested, plus our estimates of winter-wheat area sown, as derived from area harvested and percentage abandonment (U.S. Department of Agriculture, *Wheat and Rye Statistics*, Stat. Bull. 12, January 1926, p. 10); and harvested areas both winter and spring, 1885–1900. For the eastern half of Kansas included in the "Northeast," we use production and sown area of winter wheat, by counties, mainly as published by the Kansas State Board of Agriculture in successive *Biennial Reports*. Data for western Kansas included in the "Northwest," 1885–1925, are derived by subtraction of the series for eastern Kansas from state totals (winter and spring together) of the Kansas State Board of Agriculture; but from 1926, when the U.S. Department of Agriculture data for the whole state of Kansas run far above the State Board of Agriculture totals with reference especially to acreage, we derive the series for western Kansas by subtracting the series for eastern Kansas (Board basis) from state totals of the U.S. Department of Agriculture. Through the kindness of Mr. H. L. Collins of the Department, we are assured that for eastern Kansas the data of the State Board of Agriculture and the U.S. Department of Agriculture are closely similar, and that divergence occurs mainly with reference to the western half of the state.

[3] The importance of the accumulation of moisture in the soil at seeding time has been stressed in recent investigations. See especially A. L. Hallsted and O. R. Mathews, *Soil Moisture and Winter Wheat with Suggestions on Abandonment* (Kansas Agr. Exp. Sta. Bull. 273, January 1936), pp. 45–46. Because of the bearing of soil moisture on yields, attention has been directed to the desirability of plowing in the summer shortly after the crop has been harvested, so as to promote accumulation of soil moisture before seeding time.

to insure the crop harvested the next summer, even if rainfall in that summer is deficient. Accordingly the degree of relationship between yield per acre and rainfall in the calendar year of harvest is not close in the sense that high rainfall invariably results in a good yield or low rainfall in a poor yield. These considerations apply especially to the western and drier part of the region. In some years otherwise favorable, rust significantly reduces the yields; in other years hot winds in the spring or early summer do extensive damage.

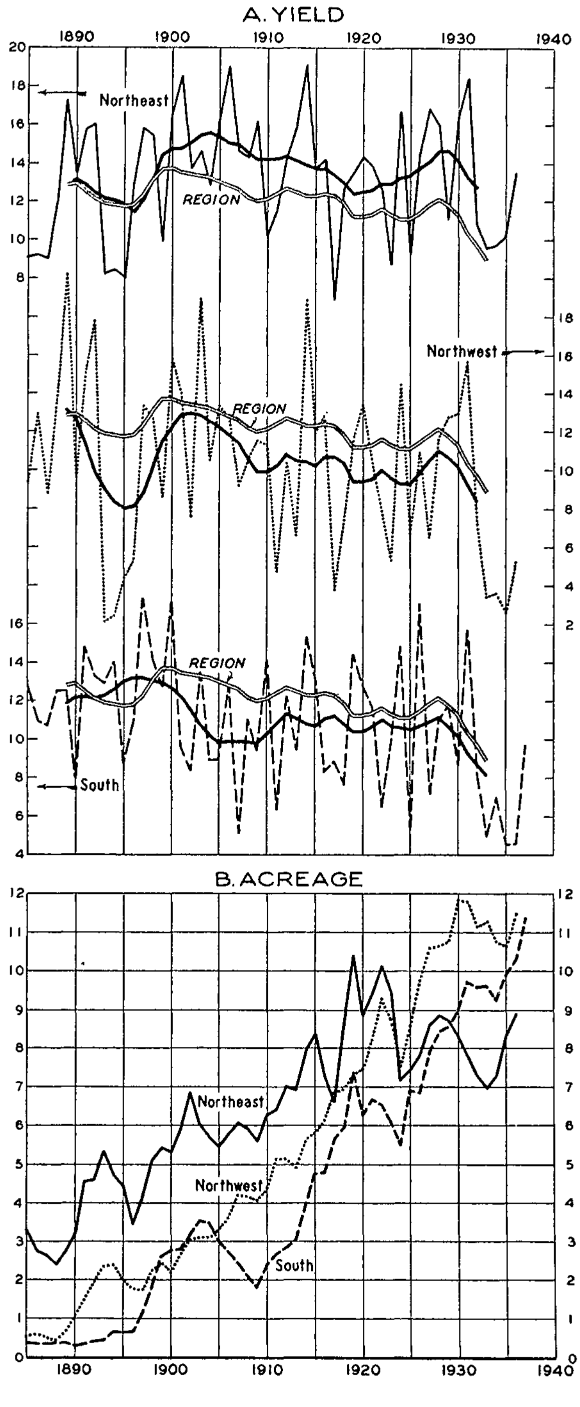
Since about 1900, yields per acre have run higher than the regional average in the Northeast, but below the regional average in the South (particularly around 1900–10) and in the Northwest (particularly after 1910). Prior to about 1900, the regional trend coincided rather closely with the trend in the northeastern section, because in these earlier years the bulk of the wheat area lay in the Northeast. In the following decade there was a steep decline of yield first in the South, then in the Northwest (due partly to incidence of drought), with accompanying rapid expansion of wheat area in the Northwest. In the South, a series of bad years immediately following the turn of the century may have restrained expansion of acreage. Under these circumstances the trend of regional yield declined, though there was little change of level in the Northeast. After 1910 the course of average regional yield was downward to 1925, upward a little to 1929, further downward thereafter; in the subdivisions the movement was diverse, especially in the South. The exceptional stability of yield in the South in the face of very rapid westward expansion of acreage after 1910 probably reflects in part the fact that long-term average yields are little if any higher in the eastern than in the western part of this section, whereas the opposite is true of the Northeast and Northwest.

In the general downward drift of regional

See also M. C. Sewell and L. E. Call, *Tillage Investigations Relating to Wheat Production* (Kansas Agr. Exp. Sta. Tech. Bull. 18, September 1925), p. 48; T. A. Kiesselbach *et al.*, *Cultural Practices in Winter Wheat Production* (Nebraska Agr. Exp. Sta. Bull. 286, April 1934), p. 3; and H. H. Finnell, "Estimation of Wheat Production Possibilities in the Panhandle of Oklahoma," *Panhandle Bulletin*, December 1933, pp. 22–36.

CHART 11.—TRENDS OF WHEAT YIELD PER ACRE (APPROXIMATE SOWN) IN SUBDIVISIONS OF THE UNITED STATES HARD WINTER REGION, AND YIELD AND ACREAGE ANNUALLY, FROM 1885*

(Bushels per acre; million acres)



* Subdivisions defined in accompanying text. The hollow lines represent trend of yield in the region as a whole, as in Chart 10.

yield per acre, especially marked after 1900, the westward expansion of wheat acreage to normally low-yielding territory is clearly perceptible. With trend-points of yield in the three sections of the region taken as recorded in 1930 but with the acreage in 1930 distributed proportionally between sections as it was in 1900, the regional trend-point of yield in 1930 would have been not 11.3 but 12.3 bushels, representing a net decline from 1900 to 1930 of 1.5 bushels rather than the recorded decline of 2.5 bushels. Moreover, there was presumably decline of yield within the Northeast and Northwest due strictly to westward expansion of acreage within each of these two sections.

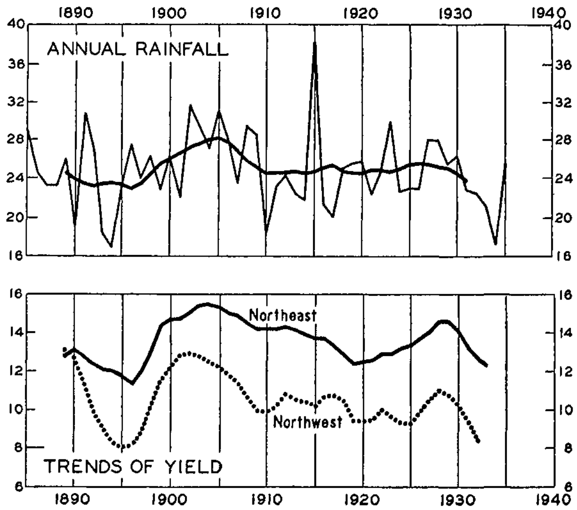
Changing weather conditions must have exerted substantial effects upon the course of the weighted nine-year moving averages of regional yields. The decline following 1929 is largely "accidental,"[1] attributable to the occurrence of drought, that was more or less widespread in every year of the period 1931–36 except perhaps 1935. Moreover, over considerable stretches of the last half a century, an appreciable degree of concordance appears between the trends of annual average rainfall in the states of Kansas and Nebraska and the trends of wheat yield per acre in the northeastern and northwestern sections of the Hard Winter region. These sections include the wheat acreage of the states to which the rainfall data apply, and not much acreage elsewhere.

This concordance appears in Chart 12. The data appear to support the inferences that the trend-points of regional yield under more stable weather conditions would have been higher in the middle 'nineties, lower around 1900,[2] and lower in the late 'twenties. With rough allowance for these weather effects, the normal level of regional yield in 1890 was perhaps nearer to 13.5 than to 12.9 bushels, in 1900 nearer to 13.0 than to 13.8 bushels, and in 1930 about at the recorded trend-point of 11.3 bushels—all per acre sown.

If so, a substantial and generally persistent decline of yield, exceeding 2 bushels per acre in about 40 years, has probably occurred from causes other than changes in the weather or climate. Without doubt the expansion of wheat acreage upon the drier and lower-yielding Great Plains of the west bulks largest among these causes. Progressive depletion of the soil under too large a degree of continuous wheat cultivation has presumably contributed to decline of yield, though on this point we have not found convincing evidence clearly

CHART 12.—ANNUAL RAINFALL (WITH TREND) IN KANSAS AND NEBRASKA, AND TRENDS OF WHEAT YIELDS PER ACRE IN TWO SUBDIVISIONS OF THE UNITED STATES HARD WINTER REGION, FROM 1885*

(Bushels per acre; inches)



* Rainfall data are annual means of statewide annual precipitation in Kansas and Nebraska compiled from J. C. Hoyt, *Droughts of 1930–34* (U.S. Dept. Int. Geol. Surv., Water Supply Paper 680, 1936), table opposite p. 4. Trend of rainfall, as of yield, is a weighted nine-year moving average (seven-year moving averages smoothed by three-year moving averages). Trends of yield per acre as in Chart 11.

[1] The moving averages for this region may not be appreciably affected by the accidental influence of statistical inaccuracies, for although basic official statistics may tend somewhat to understate the extent of decline, our adjustment to a sown-acreage basis tends to offset this understatement.

[2] In some degree, however, the higher level of yield in 1900–05 than in the middle 'nineties, especially in the Northeast, may have been due to an extraordinarily rapid shift from relatively low-yielding spring wheat to relatively high-yielding winter wheat in Nebraska. In the decade 1891–1900, spring wheat constituted 84 to 87 per cent of the total wheat acreage; in 1901–05 only 30 per cent; in 1906–10 only 11 per cent. See T. A. Kiesselbach *et al.*, *Winter Wheat Varieties in Nebraska* (Nebraska Agr. Exp. Sta. Bull. 283, July 1933), p. 6.

applicable in general.[1] Perhaps the advent and spread of "take-all" has also affected the regional trend of yield adversely. This "was first discovered in the United States in 1919, and is now known to occur in sections of Kansas and Oklahoma . . . ."[2]

Whatever the major causes of the declining trend of wheat yield in the Hard Winter region, the decline has occurred in the face of some developments tending to maintain or to enhance yields. Such were the shift from spring to winter wheat in Nebraska, practically complete by 1910; and in the extreme eastern parts of Kansas and Nebraska, some introduction of improved crop rotations and wider use of barnyard manure. A development of wider geographical application was adoption of new and higher-yielding wheat varieties, of which the two major ones were Kanred and Blackhull. These varieties, not distributed before 1917, occupied about 10 million acres in the Hard Winter region in 1929—over a third of the total area sown.[3]

Yield per acre also probably tended to be maintained by wider use of such improved practices as plowing early in the summer and harvesting promptly, both facilitated by improved motor-driven machinery.

United States Spring Wheat[4]

The United States Spring Wheat region, the second largest surplus area of the United States, lies within the states of Minnesota, North Dakota, South Dakota, and Montana. The bulk of the land area of these states is part of the northern extension of the Great Plains and the central prairies, of which the southern extension includes the wheat belt of the Hard Winter region described above. But the western third of Montana is mountainous country, and much of Minnesota is forested. The wheat-producing belt of the Spring Wheat region does not extend appreciably into these areas.

Between the western mountains and the eastern forest, the slope of the land is mostly from west to east. The soils are typically deep and fertile, mostly brown and dark brown with some black prairie soil. The smooth general topography of the plain and prairie, well adapted to large-scale machine methods of farming, is broken especially in the Black Hills of western South Dakota and adjacent "bad lands," and locally in many parts of the western Dakotas and east-central Montana. The climate is continental in type, with a summer maximum and winter minimum of rainfall, in a degree more marked than in the Hard Winter region farther south. The winters are colder, and the frost-free season is shorter but not short enough to endanger maturity of wheat except locally and rarely. Annual precipitation is somewhat lower than in the Hard Winter belt; from 25–30 inches in southeastern South Dakota and southern Minnesota, it declines in general from east or southeast to west or northwest, and is less than 15 inches throughout the eastern half of Montana. In the western half, however, precipitation increases irregularly toward the

[1] Of corn yields per acre in Kansas, however, it is asserted that long-continued decline appears not only in state averages but in eastern Kansas where acreage expansion cannot have been a dominant influence; and that "decline in corn yields in Kansas correlates closely with the decline in nitrogen and organic matter in the soil." See R. I. Throckmorton and F. L. Duley, *Soil Fertility* (Kansas Agr. Exp. Sta. Bull. 260, September 1932), p. 14. But the trend of wheat yield per acre in the eastern third of Kansas, where there has been little persistent expansion of wheat acreage since 1890, is practically stable except for temporary dips centering in the 'nineties and early 'twenties.

[2] *Yearbook of Agriculture, 1933*, p. 167.

[3] Clark and Bayles, *op. cit.*, pp. 103, 110.

[4] Discussion of the natural environment and agricultural practices of the Spring Wheat region rests largely on the following publications: the *Report of the Great Plains Committee*, C. W. Thornthwaite, "The Great Plains," A. E. Taylor, "The Contractility of Wheat Acreage in the United States," and O. E. Baker, *A Graphic Summary of Physical Features and Land Utilization in the United States*, all previously cited; also O. E. Baker, "Agricultural Regions of North America. Part VI—The Spring Wheat Region," *Economic Geography*, October 1928, IV, 399–433; L. F. Garey, *Types of Farming in Minnesota* (Minnesota Agr. Exp. Sta. Bull. 257, August 1929); L. F. Garey and F. F. Elliott, *Systems of Farming in Northwestern Minnesota* (Minnesota Agr. Exp. Sta. Bull. 268, August 1930); R. E. Willard, *The Agricultural Regions of North Dakota* (North Dakota Agr. Exp. Sta. Bull. 183, December 1924); E. A. Starch, *Economic Changes in Montana's Wheat Area* (Montana Agr. Exp. Sta. Bull. 295, January 1935); E. A. Starch, *Readjusting Montana's Agriculture. VII. Montana's Dry-Land Agriculture* (Montana Agr. Exp. Sta. Bull. 318, April 1936); C. M. Hampson and Poul Christophersen, *An Economic Study of Farms in the Spring Wheat Area of South Dakota* (South Dakota Agr. Exp. Sta. Circ. 19, May 1934).

mountains. An especially dry area extends northwesterly from southwestern South Dakota diagonally through Montana to about the center of the northern boundary, where only 12 inches of rain or less fall annually.

Not much wheat is grown in the stretch of territory thus including both the exceptionally dry belt and the Black Hills and rough lands. The acreage is sparse both here and in the mountainous territory of western Montana, the forest country of northeastern Minnesota, and in southeastern South Dakota and southern Minnesota adjoining the corn belt of Iowa. The two belts where the wheat acreage is densest thus lie in North Dakota, extending westerly into the northeastern corner of Montana, easterly into the Red River valley of Minnesota, and southerly into South Dakota a little east of its center; and in Montana between the western mountains and the dry and rough area stretching from the north-central boundary to the southeastern corner.[1]

The bulk of the wheat grown throughout the region is spring-sown wheat, mainly of the hard red type but partly durum. Winter wheat has constituted only a fifteenth to a twentieth of the total wheat acreage in the past decade. Most of the winter wheat is grown in the western half of Montana, a little in a tier of counties in southern South Dakota and Minnesota, and still less in scattered locations elsewhere. The winters throughout the major part of the wheat belt are too cold and dry to permit winter-wheat production. In this region no such significant shift from spring to winter wheat as occurred in Nebraska has been witnessed, though in South Dakota and Minnesota the ratio of winter wheat area to total wheat area has increased appreciably since before the war.

Rotations in the heart of the Spring Wheat belt (roughly central North Dakota) involve occupation of the fields by wheat two years out of four or three years out of five; when not in wheat, the land is commonly occupied one year or two by another small grain (oats, barley, rye) or by flax. Hay or intertilled crops like corn and potatoes may share one year of the rotation, but the cold dry climate and the short growing season hamper production of these crops. Consequently the typical rotation is a small-grain rotation, and suppression of weeds presents an important problem.

Toward the moister but still cool northeast of the belt, hay occupies a larger place in the rotation and wheat a smaller. Toward the moister and warmer southeast, corn and oats as well as hay displace wheat, and the problem of weed control diminishes. On the southeastern periphery of the Spring Wheat belt in southeastern South Dakota and southern Minnesota, wheat occupies well under 25 per cent of the arable acreage.

Toward the west, in central and western Montana, wheat occupies over half of the arable land, all other crops less than a fourth, and bare fallow nearly as much as the non-wheat crops. Here the use of fallow is more prominent than in any other part of the United States except the Pacific Northwest. Still farther west in intermountain valleys, about a fifth of the wheat is grown under irrigation; but the total acreage is small.

On the whole, a good deal of the wheat in the central and western parts is thus grown under practically continuous wheat or small-grain cultivation, with only occasional interruption by intertilled crops, hay, or fallow. A large fraction of the land in farms is unplowed pasture in the central part of the wheat belt, and this fraction increases toward the west and diminishes toward the east. As in the Hard Winter region, very little manure or commercial fertilizer is used except in the moister eastern stretches.

The regional wheat acreage, as appears from Chart 13,[2] has about quadrupled since the middle 'eighties—a substantial increase though far less than the increase in the Hard Winter region to the south (see Chart 10, p. 243). The wheat area of the Spring Wheat

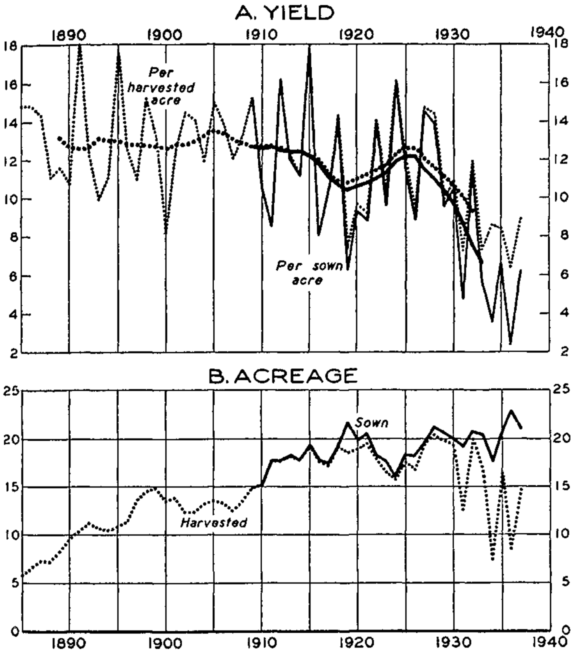
[1] See maps in *Yearbook of Agriculture, 1933*, p. 143, and M. K. Bennett and H. C. Farnsworth, "World Wheat Acreage, Yields, and Climates," WHEAT STUDIES, March 1937, XIII, opposite p. 308; also a map by C. P. Barnes and F. J. Marschner, *Natural Land-Use Areas of the United States* (U.S. Dept. Agr., 1933).

[2] This chart shows yield per harvested acre, and harvested acreage, in contrast with yield per sown acre and sown acreage so far as we can measure the acreage sown. In general, the data refer to harvested acreage only, 1885–1908; to harvested acreage of spring wheat and sown acreage of winter wheat (solid line) or harvested acreage of both (dotted line), 1909–1918; and from 1919, to harvested acreage of

region regularly exceeded that of the Hard Winter region until 1914, but expanded somewhat less during the war and much less after 1919 (cf. Chart 3, p. 225). In the Hard Winter region, expansion of acreage in the drier west was accompanied by little or no contraction in the moister east. But in the Spring Wheat region (after about 1900) the wheat acreage declined absolutely in central and southern Minnesota, eastern South Dakota,[1] and (later and less markedly) eastern North Dakota; these sections tended to become parts of the corn and the hay-and-dairy belts farther east and the wheat acreage behaved as in those belts. Meanwhile expansion of the wheat acreage occurred in the central and western Dakotas and in Montana in a degree comparable with the westward expansion in the Hard Winter region. In Montana, the last state to develop, there was but little wheat acreage prior to the liberalized Homesteads Act of 1909.[2] These tendencies are indicated crudely by Chart 14; but this chart

CHART 13.—WHEAT YIELD PER HARVESTED AND SOWN ACRE AND ACREAGE IN THE UNITED STATES SPRING WHEAT REGION, WITH TRENDS OF YIELD, SO FAR AS AVAILABLE FROM 1885*

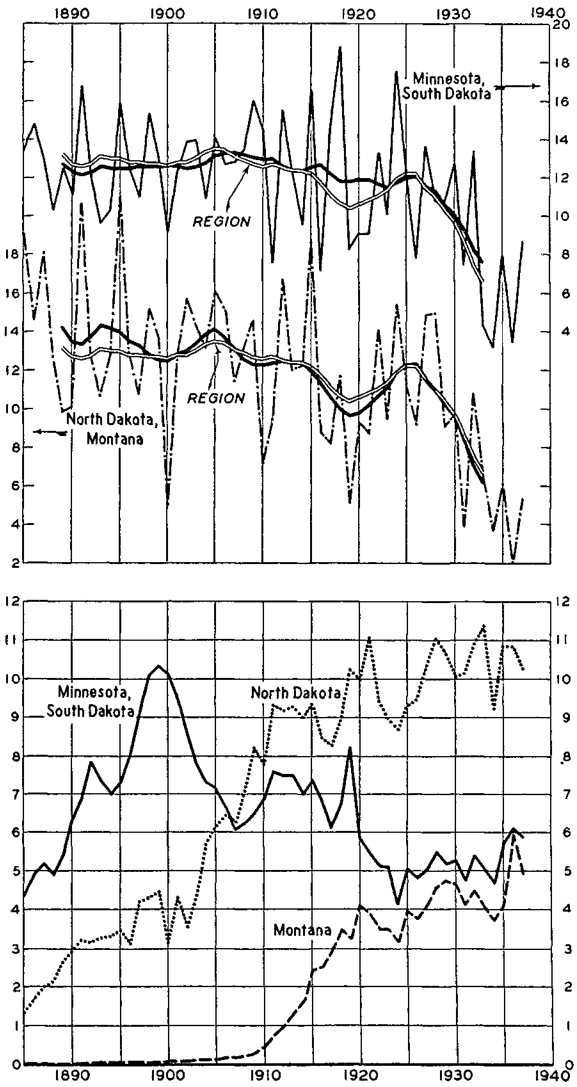
(Bushels per acre; million acres)



* See footnote 2, p. 250.

CHART 14.—TRENDS OF WHEAT YIELD PER ACRE (APPROXIMATE SOWN) IN SUBDIVISIONS OF THE UNITED STATES SPRING WHEAT REGION, AND YIELD AND ACREAGE ANNUALLY, FROM 1885*

(Bushels per acre; million acres)



* The hollow lines represent trend of yield in the United States Spring Wheat region as a whole, as in Chart 3.

both (dotted line) or to sown acreage of both (solid line). For purposes of this study we regard the statistics mainly of harvested yield per acre up to 1918 as satisfactorily comparable with the statistics of sown yield per acre from 1919, on the ground that in the earlier period the acreage was so much concentrated in the moister eastern stretches of the region that abandonment was probably of little significance.

[1] See especially wheat-acreage maps of 1890, 1900, 1910, and 1925 in O. L. Dawson, *South Dakota Farm Production and Prices* (South Dakota Agr. Exp. Sta. Bull. 225, June 1927), p. 52.

[2] See graph in *The Future of the Great Plains* . . . ., p. 41.

fails to suggest adequately the decline of acreage in the east and the expansion in the west. New settlement and encroachment on pasture contributed jointly to increase of wheat acreage in the western part of the region.

Tendencies for long-term average wheat yield per acre to decline from the moister peripheries of the Spring Wheat region toward the drier west-central part are not so clearly marked as the similar tendency for decline from east to west in Kansas. But such a retrogression is clearly perceptible in North Dakota, and also in Montana (from west to east, and irregularly perhaps on account of local prevalence of fallow). In general it is clear that the wheat acreage of the region has expanded to less favorable territory and shrunk in the more favorable territory. Chronic rust infestation, however, afflicts wheat in the moister eastern stretches[1] while more or less chronic drought afflicts the drier central stretches; hence average levels of wheat yield in the east are not so much above those in the center as might be suggested by the superior rotations and moisture supplies of the east.

Yields per acre especially in the drier central part of the belt are apparently determined to a substantial extent by the aggregate amount of rainfall during the growing season, April–July.[2] Accumulated soil moisture at seeding time in the spring, though by no means a negligible factor, is perhaps somewhat less important than is autumn accumulation in the dry part of the Hard Winter region. Something presumably depends also upon the distribution of rainfall between the four months April–July. Hot winds or widespread epidemics of rust occasionally lower yields throughout the region. Especially in the east, excessive moisture in the growing season occasionally reduces yields.

The course of the moving average of wheat yield per acre, approximately on a sown-acreage basis, was stable or only slightly downward until about 1915 (Charts 13 and 14). Then came a sharp dip centering in 1919, a bulge centering in 1925–26, and a further still sharper decline persisting at least to 1933. Chart 14, wherein are shown the course of yields in two parts of the region (respectively Minnesota and South Dakota, North Dakota and Montana), does not lend itself well to illustration of the importance of the shifting distribution of acreage.[3] But it indicates that the general drift of the yield averages was more persistently and rapidly downward in North Dakota and Montana, where acreage expansion was large, than in Minnesota and South Dakota, where the acreage tended after 1900 to contract.

In Minnesota and South Dakota, expansion of acreage prior to 1900 was mainly in relatively high-yielding territory, and the course of average yield was slightly upward. It continued so until nearly 1910, despite internal shift of acreage to less favorable territory,

[1] Willard (*op. cit.*, p. 161) gives data showing that in 11 out of 20 counties in the eastern fourth of North Dakota, rust is a more important cause of damage to wheat than any other, even drought.

[2] The substantial importance of rainfall in the growing season and the significant qualifying influence of other factors are both suggested by data referring to yields per acre in the state of North Dakota and May–July rainfall at Bismarck, N.D., in the period 1900–35. The following tabulation gives average yields (and ranges) in the 12 years of highest yields, 12 years of intermediate yields, and 12 years of lowest yields; and corresponding average rainfall (with ranges) in the months of May–July.

Yield levels	Yields (bushels) Average	Yields (bushels) Range	Rainfall (inches) Average	Rainfall (inches) Range
Highest 12	14.8	13.0–17.0	9.2	6.0–14.2
Intermediate 12 ..	10.7	8.6–12.5	8.0	4.5–15.6
Lowest 12	6.0	2.3– 8.2	6.2	3.9–10.5

The roughly corresponding gradations of rainfall and yield averages suggest the importance of rainfall in the growing season, while the ranges suggest the importance of qualifying factors. Thus a very low yield was obtained despite high rainfall (10.5 inches) in 1935, reflecting the incidence of the severest rust epidemic on record; only an intermediate yield was obtained in 1914 with the highest May–July rainfall on record at least since 1885, reflecting excess in June; and a good yield was secured in 1908 despite subnormal rainfall in May–July, when May–June rainfall was normal and only that of July was short. For a brief discussion of rust in North Dakota, see L. R. Waldron, *Stem Rust Epidemics and Wheat Breeding* (North Dakota Agr. Exp. Sta. Circ. 57, November 1935), where the years 1904, 1916, 1935, and in lesser degree 1923 and 1927 are designated as conspicuous for rust epidemics.

[3] A much more significant division of the region would involve on the one hand acreage and yield in the eastern fourth of the Dakotas and in Minnesota, and on the other hand acreage and yield in the western three-fourths of the Dakotas and in Montana. Such a division is not feasible.

partly because climatic conditions appear to have been exceptionally favorable in the first decade of the century. With continuing shift of acreage westward in South Dakota after 1910, and a series of dry years (1917–20) in the territory of east-central South Dakota where a large proportion of the acreage then lay, the averages of yield moved downward. On the reasonable assumption that weather conditions were in general about as favorable in the seven years centering in 1906 as in the seven years centering in 1926, the decline of average yield between these dates from 13.3 to 12.1 bushels seems attributable either to internal shift of acreage or to other causes excluding weather. Among these causes only reduction of soil productivity on account of loss of fertility seems to be mentioned in the available discussions; and perhaps little weight need be assigned to this because so large an expanse of the acreage in these states remained in areas that were gradually converted to general-farming regions with improved rotations and wider use of manure. The steep decline of yield trend in these states after 1926 must reflect mainly drought (May–July rainfall has been below normal in every year of the period 1929–36 except 1935), together with rust in 1935. There was little or no westward shift of acreage after 1926.

In North Dakota and Montana, the broad effects of changing weather conditions and internal shifts of acreage can be suggested numerically. Conspicuous bulges of average yield per acre center in 1893, 1905, and 1926; conspicuous depressions center in 1900, 1919, and 1932. The following tabulation shows yield-averages centering in these years in contrast with average May–July rainfall at Bismarck, North Dakota, and average wheat acreage in the two states:

Center of period	Yield[a]	Rainfall[b]	Acreage[c]
1893	*14.3*	*7.9*	*3.35*
1900	12.5	7.3	4.05
1905	*14.1*	*8.6*	*5.95*
1919	9.7	6.0	13.24
1926	*12.3*	*8.2*	*13.65*
1932	7.2	6.7	14.56

[a] Bushels per acre; weighted 9-year average.
[b] Inches in May–July; 7-year averages centering in designated years; normal rainfall, 7.9 inches.
[c] Million acres; 5-year averages centering in designated years.

Periods of relatively low yield were clearly periods of subnormal May–July rainfall, while periods of relatively high yields (in italics) were periods of normal rainfall or above. At the same time a downward drift of yield appears with reference alike to successive periods of relatively high yields and to successive periods of low yields, so that decline assignable to non-accidental factors is probable, even with full allowance for the possibility that the statistics overstate the declining tendency.

This downward drift must in large part reflect the internal geographical shift of acreage.[1] The wheat area lay almost entirely in the eastern fourth of North Dakota in 1889 and in the eastern half of 1899, but by 1909 had spread to the western boundary, by 1919 had moved also into Montana from both east and west, and by 1929 and subsequently had increased in density throughout both western North Dakota and the central and eastern belts of Montana. Following 1909 or earlier, the acreage decreased in eastern North Dakota while expanding in the west.

Such shifting of acreage, involving expansion into low-yielding territory and contraction in high-yielding territory, must go far to explain the decline of yield due to non-accidental factors not only in North Dakota and Montana, but in the Spring Wheat region as well, at least in the present century. Prior to 1900, the shifting of acreage was probably not an important adverse influence in the region as a whole, but it assumed large importance after about 1910.

Other yield-depressing factors may have been increasing weediness of fields, and reduction of soil productivity through drafts upon organic and mineral constituents induced by much continuous cropping. These were presumably less prominent in the eastern part of the region where crop rotations improved as wheat lost its predominance. Wind erosion has been mapped as "severe" in wide stretches especially of the Dakotas.[2]

[1] See maps in *Yearbook of Agriculture, 1933*, pp. 141–43, and O. E. Baker, *A Graphic Summary of American Agriculture Based Largely on the Census* (U.S. Dept. Agr. Misc. Pub. 105, May 1931), pp. 43–46.

[2] *The Future of the Great Plains* . . . ., p. 29. When erosion proceeds so far that it forces abandon-

Not all of the non-accidental influences, however, operated in the direction of depressing the trend of wheat yield in the Spring Wheat region since around 1905. In general throughout the region, improved wheat varieties have been introduced[1] and mechanization of agriculture since the war has presumably facilitated timely plowing, seeding,[2] and harvesting; and in the eastern stretches crop rotations have improved and use of manure has become more general. These factors tended to sustain or augment yields, but failed to offset the adverse effects principally of shift of acreage, secondarily of continuing drafts upon soil productivity.

Prairie Provinces

The Prairie Provinces of Canada (Manitoba, Saskatchewan, Alberta) represent, in their settled agricultural area, the northernmost extension of the Great Plains and prairies of the central United States. This agricultural area lies in the form of a vast right-angled triangle with its base on the international boundary, its perpendicular in the west passing due north about through central Alberta up to the center of the province, and its hypotenuse descending southeasterly to the eastern corner of Manitoba. On the west, this area is bounded by mountains and by a cold zone where, although the mountains recede toward the northwest, the length of the growing season is normally less than 100 days. Northward and eastward of the hypotenuse of the triangle, heavily wooded lake and muskeg areas and barren rocky waste lands prevail.[3] Within the agricultural area, the slope of the land is from west and southwest to east and northeast, descending gradually except at two escarpments rather sharply defined. As in the United States farther south, the topography is well adapted to machine methods of farming.

The climate is continental in type, as is that of the United States Spring Wheat belt. The winters, however, are colder, the summers somewhat cooler, the growing season shorter. Annual rainfall is about the same, though no part of the agricultural area of the Prairie Provinces receives as much rain as Minnesota, the eastern fringe of North Dakota, and the eastern third of South Dakota. The driest and warmest part of the agricultural zone of the Prairie Provinces lies in southeastern Alberta and southwestern Saskatchewan, a continuation of the belt of dry or rough land that extends northwesterly through the Spring Wheat region of the United States (see p. 250). Here, except as interrupted by the higher elevations of the Cypress Hills, less than 13 inches of rain fall annually. But from this relatively dry district the precipitation tends to increase toward the west, east, and north, though considerably less markedly toward the north. It is about 19 inches along the western perpendicular of the agricultural triangle, about 20 in the extreme eastern angle, but only about 15 in the middle of the hypotenuse in central Saskatchewan. With declining temperature from south to north, evaporation[4] is lower in the agricultural belt of the Prairie Provinces than in most of the United States Spring Wheat belt. Hence, since precipitation is about the same in the two regions, somewhat more moisture is probably available for plant growth in the Prairie Provinces.

The soils of the two regions are also similar in structure and fertility. In the agricultural region of the Prairie Provinces, the lighter-colored brown soils center about the driest and warmest area in southeastern Alberta and

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ment of farms, it may well be regarded as a favorable influence on trend of weighted average yield because it may reduce the relative weight of low-yield acreage.

[1] Such improved varieties (either rust-resistant, drought - resistant, or early - maturing) as Ceres, Thatcher, Hope, and Supreme, were unknown until after 1920 but now constitute probably between a fourth and a half of the regional wheat acreage; and Marquis, the leading variety, was introduced about 1913.

[2] In this region, it is said that "spring plowing may produce slightly greater yields" than fall plowing and that seeding should be begun "as soon as the frost is out of the ground and the land can be prepared" (*Yearbook of Agriculture, 1933*, pp. 155–56). These operations can be accomplished more rapidly with tractors than with horses.

[3] The Peace River country, an isolated agricultural region, lies in Alberta northwest of the apex of the triangle, separated from the main agricultural area by an outcropping of high land and a zone of low temperature.

[4] See map in J. P. Goode, *Goode's School Atlas* (New York, etc., 1932), p. 69.

southwestern Saskatchewan, and are surrounded on west, north, and east by increasingly darker soils merging into the black prairies of the Red River valley in the eastern extension of the agricultural triangle. These encircling dark soils coincide roughly with the so-called "park belt,"[1] where the natural vegetation is tall grass interspersed with groves of poplars; while the lighter soils coincide with the treeless short-grass plain. Passing outward through the park belt, one encounters lighter and leached forest soils.

The wheat acreage of the Prairie Provinces is nearly coextensive with the agricultural area.[2] It is relatively least dense in the driest part, where grazing dominates; and along the outer portion of the park belt, where other crops occupy a larger fraction of the crop area than wheat. Between this inner grazing area and outer mixed-farming area, wheat exceeds all other field crops in acreage.

The prevalent system of wheat production involves rotation of wheat with fallow, and with other small grains or flax. Hay and intertilled crops play but a small rôle because of the short growing season. Manure and commercial fertilizer are used very little, and mainly in the east. Within the main wheat region, fallow and wheat often occupy the land alternately; or, more frequently, fallow is succeeded by wheat for two years,[3] or by wheat one year and half wheat and half oats the second year.[4] Animals are maintained chiefly on natural pasture. As one passes into the more humid park belt, the fallow may be used less frequently and oats or barley may assume greater importance. Particularly in the eastern extremity of the agricultural triangle, rotations involving hay crops have made inroads on the fallow-and-small-grain system, and there is more feeding of livestock and greater use of manure; but even here the great bulk of the land not in fallow is used for the small grains.

The fallow occupies so large a place, as compared with the Spring Wheat belt of the United States, partly because it probably conserves moisture better in the Prairie Provinces and therefore gives larger differential yields of wheat; and partly because intertilled crops are more difficult to bring to maturity and resort must be had mainly to fallow for control of weeds. Largely because of the relative prevalence of fallow in the Prairie Provinces, wheat yields per acre average considerably higher than south of the international border. Perhaps, however, there would be a differential advantage due to the more favorable precipitation-evaporation ratio under identical methods of culture. Within the Prairie Provinces, yields per acre of wheat diminish somewhat systematically from the peripheral park belt toward the drier south-central area; but a relatively low-yield district extends upward in Saskatchewan close to the northern high-yield fringe,[5] following in general the similar extension of the low-rainfall zone.

The wheat grown in the Prairie Provinces is exclusively spring-sown except for a trifling amount of winter wheat in southwestern Alberta. The spring wheat is mainly of the hard red type, though durum is grown especially in the east where the hazard of rust is greatest. Drought is the major hazard, as in the United States Spring Wheat belt. Largely on account of the wider use of fallow, annual fluctuations of yield in Canada probably depend somewhat less upon fluctuations of rainfall during the growing season, somewhat more upon accumulation of soil moisture at seeding time. Risk of crop damage from frost is greater than in the United States, so that early spring sowing is even more desirable. Spring plowing of stubble land affects wheat yields somewhat favorably in both belts, but is a practice more difficult to follow in Canada because of the urgency of sowing early and thus avoiding risk of damage from early autumn frosts. The major problem of

[1] See map in Baker, "Agricultural Regions of North America. Part VI—The Spring Wheat Region," p. 400.

[2] See maps in Canada, Dominion Bureau of Statistics, *Agriculture, Climate and Population of the Prairie Provinces of Canada: A Statistical Atlas . . . .* (Ottawa, 1931).

[3] C. P. Wright and J. S. Davis, "Canada as a Producer and Exporter of Wheat," WHEAT STUDIES, July 1925, I, 224.

[4] Crop rotations in various "sample areas" of the Prairie Provinces are described in R. W. Murchie *et al., Agricultural Progress on the Prairie Frontier* (Toronto, 1936).

[5] Bennett and Farnsworth, *op. cit.*, map opposite p. 308, and tables p. 303.

wheat breeding is to develop varieties of hard red spring wheat that at the same time mature early, yield well, resist drought and rust, and yet are of the premium high-protein types which constitute the bulk of the huge Canadian exports.

Wheat production on a large scale in the Prairie Provinces developed later than in any other of the fourteen regions considered in this study. The total wheat area did not exceed 5 million acres until 1906, and was then smaller than the acreage in the other four regions where large expansion has occurred in the past 50 years (see Charts 2 and 3, p. 225). But by 1921 the Prairie Provinces contained a larger wheat acreage than either Australia, South America, or the United States Spring Wheat belt, though still surpassed by the United States Hard Winter region. This relative position has been maintained in recent years. Of the three provinces, Manitoba was the first to be settled, and her period of expansion was over by 1910 (Chart 15, lower tier). Saskatchewan followed, increasing her wheat area nearly 8 million acres between 1905 and 1915. In Alberta expansion barely began before 1910.

The moving averages of regional yield per acre (Chart 3, p. 225, and hollow lines in Chart 15) tended slightly upward until just before the war. Much as in the United States Spring Wheat belt, a depression followed, centering about in 1920, and this in turn was succeeded by a bulge centering in 1925 or 1926 and another sharp decline to a new low level. The peak averages of yield in 1925–26 were lower than in 1913 and the low average in 1933 was lower than that of 1920, suggesting a reversal of underlying tendency beginning just before the war.

The slightly rising course of the averages up to the war seems to reflect the operation of counteracting factors. Accidental influences assisted this prewar rising tendency. There is a presumption that rainfall was on the average more abundant in the second half of the period 1885–1915 than in the first,[1] and some degree of official overestimation of yield seems probable in some of the years (1909, 1911–13) just preceding the war.[2] Non-accidental factors assisting the rising prewar tendency included, up to about 1915, expansion of acreage largely in relatively high-yield territory—Manitoba and the park belt of Saskatchewan and Alberta—though partly also in the drier region of central Saskatchewan.[3] After 1909, the newer and higher-yielding variety Marquis within a few years largely displaced Red Fife.[4] Finally, the wheat acreage in the years of very rapid expansion between 1905 and 1915 must have been sown in relatively large proportion on newly broken ground; and, since farmers in this region usually obtain exceptionally high yields for a few years after new breaking, a period during which the ratio of sowings on new breaking to total sowings is high is likely, other influences equal, to be a period of relatively high average yield.[5] These influences sufficed to outweigh such adverse factors as depletion of soil fertility in the older part of the region (resulting in part from soil-blowing to which the prevalence of fallow contributed); increasing weediness of fields due at least partly to concentration on small-grain cultivation; and possibly an increasing prevalence of wheat pests and diseases (mostly rust).

In the decades following 1915, the course of the moving averages of yield in the Prairie Provinces was irregularly downward. In this period the accidental influences reversed their effect. Thus the statistical bias apparently tended slightly to exaggerate the level of yield just before the war but not subsequently; and, more important, the succession of seasons seems to have been less favorable for ade-

[1] Based on analysis of annual rainfall at eight stations in the Prairie Provinces, as published in E. S. Hopkins *et al.*, *Soil Drifting Control in the Prairie Provinces* (Canada Dept. Agr. Bull. 179, n.s., 1935), pp. 38–39.

[2] Bennett, *op. cit.*, p. 77.

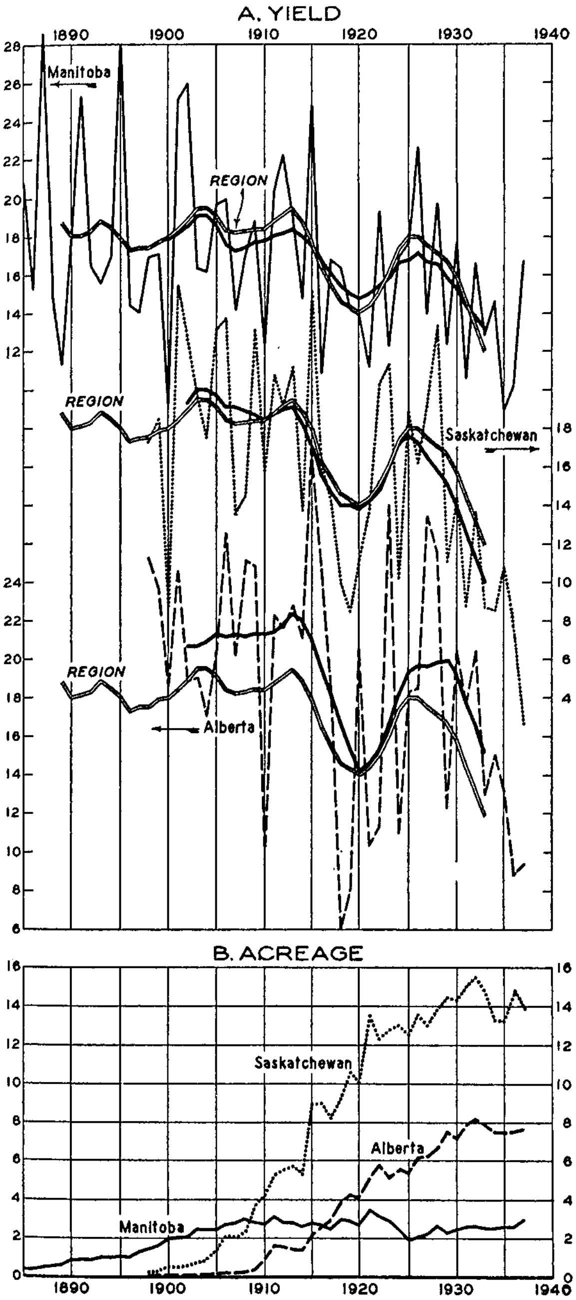
[3] See dot maps in *Statistical Atlas . . .*, *op. cit.*, pp. 32–34.

[4] *Statistical Atlas . . .*, *op. cit.*, p. 32; A. H. R. Buller, *Essays on Wheat* (New York, 1919), pp. 154–58.

[5] This inference is most clearly applicable to regions where expansion of acreage is mainly into new territory characterized by normal yields about as high as in older territory, and where the differential yield on new breaking as compared with older land is substantial. The trend of wheat yield in the Prairie Provinces seems to be the only regional trend of the fourteen here considered that was appreciably affected by this combination of circumstances and developments.

CHART 15.—TRENDS OF WHEAT YIELD PER SOWN ACRE IN SUBDIVISIONS OF THE PRAIRIE PROVINCES (CANADA), AND YIELD AND ACREAGE ANNUALLY, FROM 1885*

(Bushels per acre; million acres)



* The hollow lines represent trend of yield in the Prairie Provinces as a whole, as in Chart 3.

quate moisture supplies than the succession preceding the war.[1] Two of the non-accidental influences also reversed their effect: the wartime and postwar expansion of acreage was predominantly in the dry and relatively low-yielding parts of the wheat belt; and the proportion of wheat acreage sown on new breaking was much less in the past decade than just before and during the war. Certain other unfavorable influences continued so—depletion of soil fertility, increasing weediness of fields,[2] and (possibly) spread of pests and diseases.

The downward trend of yield adjusted for accidental influences was thus due to the aggregate operation of these adverse factors, which more than offset certain favorable developments. Of these the more prominent were probably the spread of mechanization, facilitating timely soil preparation and seeding; the advent of improved techniques for managing the fallow, including cultivation of crop and fallow in strips rather than blocks, use of cover crops, and preparation of a cloddy rather than a smooth surface; the improvement of wheat varieties; some increase in the proportion of the wheat acreage sown on fallow; and in the east some enlargement of the relative area in hay and intertilled crops—an improvement of the rotation.

So far as we can ascertain, the province of Manitoba is the only region or sub-region here considered where internal shifting of acreage cannot have had a significant adverse

[1] Protracted droughts, or at least successive seasons of abnormally low rainfall in the growing season, account mainly for the marked depressions of yield of which the first centers in 1920 and the second extends to 1933, though 1916 and 1935 were years of severe rust epidemics. The period of drought centering in 1933 was presumably worse than that centering in 1920, so that for climatic reasons alone one would expect a lower level of yield around 1933 than around 1920. It seems impossible to say whether climatic conditions were more or less favorable in the period centering in 1925 or 1926 than in the period centering in 1913; but the latter period cannot have been significantly better. Hence it seems likely that some of the decline in yield from peak of 1913 to peak of 1925–26 and from trough of 1920 to trough of 1933 is attributable strictly to weather developments.

[2] "A survey of the distribution and prevalence of seven weeds, judged to be the worst in this area, showed that six of them, all introduced plants, are prevalent roughly in proportion to the age of settlement in the various parts of the west." R. Newton, "Wheat-Growing in the Prairie Provinces of Canada," *Proceedings of the Fifth Pacific Science Congress, Canada, 1933* (Toronto, 1934), IV, 604.

effect upon wheat yield, where at the same time some improvement of rotations and increasing use of manure have been in evidence, and yet the yield per acre has tended to decline for about 40 years.[1] Here both climate and distance from markets operate to prolong the dominance of a cropping system of small grains and fallow, giving relatively wide scope for depletion of soil fertility and prevalence of weeds, pests, and diseases.

III. TREND OF "WORLD" YIELD

The course of weighted nine-year moving averages of "world" yield per acre[2] is shown by the hollow lines in Charts 16 and 17. There has been conspicuously little fluctuation; the maximum range is only 1.5 bushels between the lowest average (13.4 bushels in 1918) and the highest (14.9 bushels in 1906). All of the fourteen regional moving averages of yield move through wider ranges than this. In substantial degree, the various factors that influence slope and conformation of the world moving averages of yield have been compensatory or offsetting in their effects.

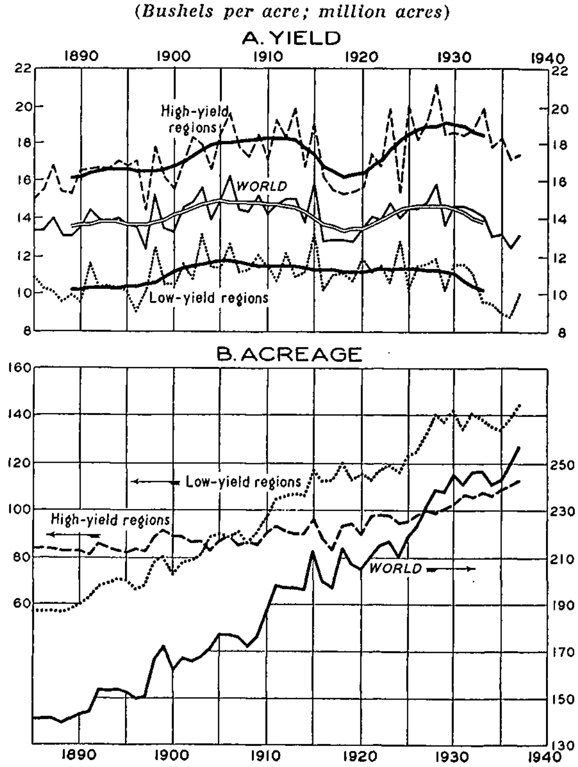
Accidental Influences

Statistical inaccuracies and exceptional sequences of weather may be regarded as accidental influences—certainly not exerted by the men who till the soil—on the course of the moving averages of world yield per acre.

The major effect of statistical inaccuracies is somewhat to understate the general level of world yield in the period preceding 1900. In later years the effects of these inaccuracies may reasonably be supposed to be negligible with reference to a territory as large as that included in the "world" total. In the period prior to 1900, more or less understatement of the level of yield probably affects the moving averages not only for the world, but also for each of the four different divisions of it shown in Charts 16 and 17. It seems impossible to ascertain what particular portion of the moving average of world yield is most affected by statistical understatement in the period preceding 1900; but it seems likely that the correction was gradual rather than abrupt.

Chart 16.—"World" Trend of Wheat Yield per Acre, and Trends in High-Yield and Low-Yield Regions, with Yield and Acreage Annually, from 1885*

(Bushels per acre; million acres)



* High-yield regions are Northern Europe, France, Italy, Southeastern Europe, Eastern North America, United States Soft Winter, Pacific Northwest, and Prairie Provinces. Low-yield regions are India, Western Mediterranean, United States Hard Winter, United States Spring, Australia, and South America. The basis of classification is weighted nine-year averages centering in 1910 and 1930; high-yield regions had yields of 15 bushels or more at these dates, low-yield regions yields of 12.6 bushels or less.

With reference to weather developments, there is no good basis for characterizing stretches of years as exceptionally good or bad weatherwise in a "world" wherein the acreage

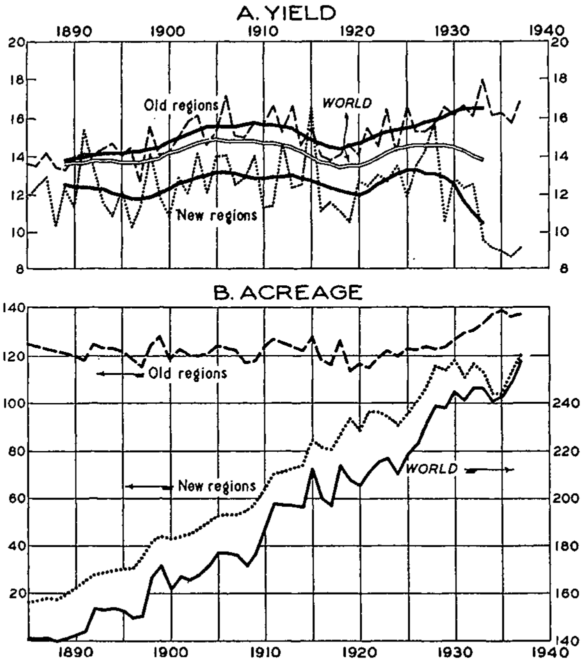
[1] Similar developments might, however, be found in some subdivisions of the various sub-regions considered in this study if the breakdown of statistical data had been carried farther.

[2] The "world" includes only the fourteen regions previously considered. An inclusive "world" would cover also Soviet Russia, China, Turkey, and Persia, and some other countries. The trend of wheat yield in the world as a whole is conjectural, but would almost certainly differ from the trend shown in Charts 16 and 17.

of wheat has expanded greatly and the sort of weather most favorable or most unfavorable for wheat differs from region to region and is not well understood. Our impression is, however, that world weather developments find reflection in four portions of the curve of world yield. Exceptionally unfavorable world

CHART 17.—TRENDS OF WHEAT YIELD PER ACRE IN "OLD" AND "NEW" REGIONS, WITH YIELD AND ACREAGE ANNUALLY, AND TREND OF "WORLD" YIELD, FROM 1885*

(Bushels per acre; million acres)



* "Old" regions are Northern Europe, France, Italy, Southeastern Europe, Western Mediterranean, India, Eastern North America, and United States Soft Winter. "New" regions are United States Hard Winter, United States Spring, Prairie Provinces, Pacific Northwest, Australia, and South America. The basis of classification is percentage change in acreage, 1890 to 1930; in "new" regions, the acreage at least doubled, while in "old" regions the acreage either declined or rose by less than 50 per cent.

weather accounts perhaps fully for the failure of the trend of world yield to rise in the middle and late 'nineties.[1] The bulge of yield centering in 1905 probably represents exceptionally favorable world weather. The deep depression centering in 1918 reflects unfavorable weather in large degree but not exclusively.[2] And the dip beginning in 1929[3] is a phenomenon due very largely to exceptionally adverse weather, in this instance localized in the Great Plains of North America. As appears from Chart 17, the course of average yield dipped sharply downward in the "new" regions dominated by those lying in the North American plains, whereas there was progressive increase of yield in the "old" regions.

A trend of world wheat yield corrected for these accidental influences would differ somewhat from the curves shown in Charts 16 and 17. The initial level would be a little higher and the slope would probably continue persistently upward until around 1910, though perhaps less rapidly after 1900 than before. The level would be higher especially in the middle and late 'nineties, but somewhat lower in several years around 1905. The depression centering around 1918 would remain perceptible, but of smaller dimensions; the general level in the years 1925–30 might remain about unchanged; and the dip beginning with 1929 would be greatly modified. A trend-increase of world yield attributable to other factors than accidental ones and amounting to perhaps 0.7 or 0.8 of a bushel occurred between 1890 and 1910; and a generally declining tendency (accentuated during the war) prevailed between 1910 and 1930 but amounted to only 0.1 or 0.2 of a bushel. Reversal of the direction of "adjusted" trend probably occurred shortly before the war, approximately in the middle of the period 1885–1937.

FUNDAMENTAL TREND-INFLUENCES

Three interacting factors seem to account for the broad conformation of this "adjusted" world trend: the adoption of new and higher-yielding types and varieties of wheat; man-made changes in agricultural technique af-

[1] The slight depression of yield in the 'nineties would almost certainly have been much more prominent if the central plains of North America had then contained as large a wheat acreage as in recent years.

[2] Depressions of yield were marked in certain regions (Eastern North America, South America, the Pacific Northwest, the United States Spring Wheat region, and the Prairie Provinces) remote from war influences; and weather records point clearly enough to exceptionally adverse effects on yield not only in these regions but in those strongly affected by shortage of fertilizer, labor, or draft-power (Northern Europe, France, Italy, Southeastern Europe).

[3] This dip, brought to 1933 in the chart, will be carried further even in the unlikely event that world yields in each of the years 1938–40 reach 15 bushels per acre.

fecting the environment of the wheat plant; and shifting of wheat acreage.

In general, adoption of new types and varieties of wheat has tended without interruption to increase world wheat yields. Shifts in the types of wheat produced (from spring to winter) were important locally but not generally; and these occurred mainly in the first half of the period under review. Shifts to new varieties were important generally. In the main, these shifts occurred in the latter part of the prewar period and throughout the war and postwar periods. One may reasonably conclude that larger favorable influence upon yield was exerted by adoption of new types and varieties in the period after 1910, when "adjusted" world yield declined, than in the period before 1910, when world yield increased.

Except during and just after the war, changing agricultural techniques have presumably favored persistent though irregular trend-increase of world yield per acre. There was probably no moderately large area wherein the techniques common in 1910 were not superior to those common in 1890; and there is only one area (the eastern part of Southeastern Europe) where techniques common in 1930 were not superior to those common in 1910. Of the several forms of improvements in technique, irrigation and controls of pests and diseases seem relatively unimportant. In humid areas, the changes of technique effective in combating ever-present tendencies to deplete soil fertility have been mainly wider use of fertilizer, improvement of crop rotations, and more intensive use of labor; and in drier areas, improved methods of soil preparation and management (facilitated by the spread of machinery), with much less change in rotations or in use of fertilizer. A much larger fraction of the world wheat acreage lay in semiarid territory after 1910 than before. Since wider use of fertilizer and effective shifting of crop rotations appear to be relatively the most successful devices for increasing wheat yields but cannot be used widely in most dry territory, it seems probable that changes in agricultural techniques were rather more effective in increasing world wheat yield before 1910 than after.

If, then, world yield per acre adjusted to eliminate effects of weather and statistical inaccuracies rose before 1910 but declined thereafter, the reversal of trend is not due either to general or important localized retrogression of agricultural technique, or to slower development of new wheat varieties. It is fundamentally due to shifting of the proportions of the world wheat acreage lying respectively in relatively humid areas with normally high yields and large capacity for increase, and in relatively arid areas with normally low yields and smaller capacity for increase. Chart 16 shows trends of yield respectively in high-yield regions and in low-yield regions; the high-yield regions, however, include three (the Prairie Provinces, the Pacific Northwest, and Southeastern Europe) where levels of yield are high[1] but capacity for increase is relatively limited. This chart indicates that the proportion of the world wheat acreage in low-yielding regions has increased progressively until the past decade. At the same time the yield per acre has been falling since 1905 in the low-yield regions, a development due in large part to shifting of acreage within those regions into drier and drier low-yielding territory where the weapons available to combat depletion of soil fertility and weed infestation are relatively limited. And even in the high-yield regions, the general upward trend of yield was restrained by expansion of acreage into the three regions where capacity to increase yields is small.

Chart 17 carries similar implications. Until 1905 or a little later, yields per acre were rising not only in old regions, a group where humid territory weights the total heavily and where in general the climates give wide scope to improved techniques, but also in the new regions where the drier climates impose narrower limits on available techniques. In these new regions the early expansion of acreage involved much good land and accompanied technical improvements. But after about 1905, expansion of acreage was toward progressively drier and lower-yielding land and

[1] The level of yield in the Prairie Provinces and the Pacific Northwest is high because so much wheat is grown on fallow. The yield per acre of "land devoted to wheat" would be ranked not high, but low.

this offset continuing improvement of techniques and introduction of new varieties; and the trend of yield in the newer regions failed to rise further while the trend in the older regions continued upward (with wartime interruption). The low level of yield and its failure to rise in the new regions, coupled with their continually increasing importance, eventually reversed the trend of world yield in spite of continuing increase of yield in the higher-yielding old regions.

Initial Level of Yield and the Future Trend of Yield

In detailed study of the fourteen regions that make up the "world," we have found little occasion to stress the importance of the levels of wheat yield characteristic of regions and subregions early in the period under review. In certain subregions of Western Europe, however, it seemed probable that yields in the late 'eighties might already have reached so high a level that increase of yield comparable in magnitude to that previously achieved could not be expected to be repeated, at least with farmers operating in fields rather than greenhouses. An undefined and undefinable upper limit of yield was probably being approached in these few subregions nearly half a century ago.

In the course of the past half-century, such subregions as these have presumably witnessed a still closer approach to their undefinable upper limit of wheat yield per acre. Moreover, certain regions where the level of yield in the late 'eighties offered wide scope for improvement must have achieved by 1935 a substantial fraction of the potential increase (e.g., Italy, Germany, northern France, Ontario). The initial level of yield will perhaps assume larger importance if ever an attempt is made to trace the history of yield from 1935 to 1985, because more areas today stand near the point where further increase of yield must be difficult and slow than was the case in 1885.

Merely on this account, it will be surprising if the trend of yield, abstracting from accidental influences, in either the "high-yield" regions of the world (Chart 16) or the "old" regions (Chart 17) increases as much between 1930 and 1970 as between 1890 and 1930.

But the trend of world yield per acre in the future will depend, as in the past, upon interaction of opposing tendencies; and, ignoring statistical inaccuracies and the vagaries of weather, upon continuing development of new varieties, the discovery and spread of improved techniques, and the changing distribution of acreage. The unfavorable effects of progressive concentration of wheat acreage in dry low-yield territory, where the scope for effective yield-maintaining practices is relatively narrow, may reasonably be expected to be in evidence as they have been since 1910. If governmental encouragement of wheat production should be gradually removed in humid high-yielding regions (eastern United States, importing countries of Europe), these effects will presumably be strengthened as acreage in the humid regions declines.

There is thus some reason to anticipate in the next half-century a smaller increase of yield (abstracting from statistical errors and weather) in old regions of the world than occurred between 1885 and 1935; perhaps a horizontal or slightly declining trend of yield in the new regions; and an increasing rather than a diminishing fraction of world wheat acreage in the new regions. Under such circumstances it might seem reasonable to anticipate a declining tendency in world yield. But much depends upon the probable extent of change in these factors as well as upon unforeseeable changes in wheat varieties and agricultural techniques, and the outlook is in fact far from clear.

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