

University of Nebraska - Lincoln

DigitalCommons@University of Nebraska - Lincoln

Great Plains Quarterly

Great Plains Studies, Center for

1986

RIVER CONSERVANCY AND AGRICULTURAL DEVELOPMENT OF THE NORTH CHINA PLAIN AND LOESS HIGHLANDS STRATEGIES AND RESEARCH

Huang Bingwei
Chinese Academy of Sciences

Follow this and additional works at: <https://digitalcommons.unl.edu/greatplainsquarterly>



Part of the [Other International and Area Studies Commons](#)

Bingwei, Huang, "RIVER CONSERVANCY AND AGRICULTURAL DEVELOPMENT OF THE NORTH CHINA PLAIN AND LOESS HIGHLANDS STRATEGIES AND RESEARCH" (1986). *Great Plains Quarterly*. 977.
<https://digitalcommons.unl.edu/greatplainsquarterly/977>

This Article is brought to you for free and open access by the Great Plains Studies, Center for at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Great Plains Quarterly by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

RIVER CONSERVANCY AND AGRICULTURAL DEVELOPMENT OF THE NORTH CHINA PLAIN AND LOESS HIGHLANDS STRATEGIES AND RESEARCH

HUANG BINGWEI

The North China Plain is the Chinese counterpart to the North American Great Plains. This largest plain in China suffers frequently from drought. Although agricultural production has been significantly increased in recent years, it is still far too low and too unstable to compensate for population growth and the demands of a rising standard of living. One of the major factors limiting agricultural development on the North China Plain is drought. A complication is that not only have surface and underground water resources been utilized almost to their limits for agrarian needs but also water shortages due to rapidly mounting urban and industrial demands have become more and more acute. At the same

Huang Bingwei, one of China's most eminent geographers, is honorary director of the Institute of Geography, Chinese Academy of Sciences. The author of several books, including Physico-geographic Regions of China (1959), and numerous articles, he has been since 1954 a member of the Chinese Academy of Sciences, the highest honor of the People's Republic of China.

time, perhaps ironically, too much water is also a menace to the North China Plain. Poor drainage and soil salinization are characteristic of extensive areas, and the potential hazard of inundations from the Yellow River is a historic and worsening problem.

In formulating a sound antidrought strategy for the North China Plain, scientists must investigate both conditions, too little and too much water. Furthermore, they must remember that the North China Plain and the contiguous Loess Highlands are similar in many important respects. Indeed, they are geologically inseparable in their formation and transformation through the medium of running water. Therefore, no wise solution to the problems of the North China Plain can be proposed if the latter is treated in isolation from its neighboring highlands. A comprehensive yet still preliminary study of the area has, in fact, revealed that only properly coordinated measures aimed at making the most of precipitation in situ will address adequately the major water-regime problems of the Plain.

The North China Plain and the Loess Highlands are the cradle of the Chinese nation and have a history of agriculture dating back more than forty centuries. With their northern

and southern boundaries corresponding, respectively, to the isotherms for absolute minimum temperature of -21° or -22°C and a January isotherm of 0°C , the thermal regime of these regions is suitable for the successful growth of winter wheat in the absence of protective snow cover but is too cold for the production of vegetable crops in winter. Double cropping is possible where there is sufficient moisture supply. The annual precipitation ranges from 250 to 800 mm, against an annual potential evapotranspiration of approximately 1000 mm.

The environment is neither arid (because crop production may be conducted without irrigation) nor humid (because soil salinization

is a common feature in depressed areas with water table less than 1.5 m below the surface). Perhaps *semiarid* and *subhumid* are appropriate adjectives for the drier and wetter parts, respectively. However, there is no clear demarcation between these two areas. In a water-plant relation analysis, the seasonal distribution of precipitation is more important than the annual amount. Late summer and early autumn are generally the times when rainfall surpasses evapotranspiration and the soil water reservoir is recharged, often to field capacity. However, this period is followed by a long period of little precipitation, beginning in the middle of September and lasting through the winter and into late spring or even early

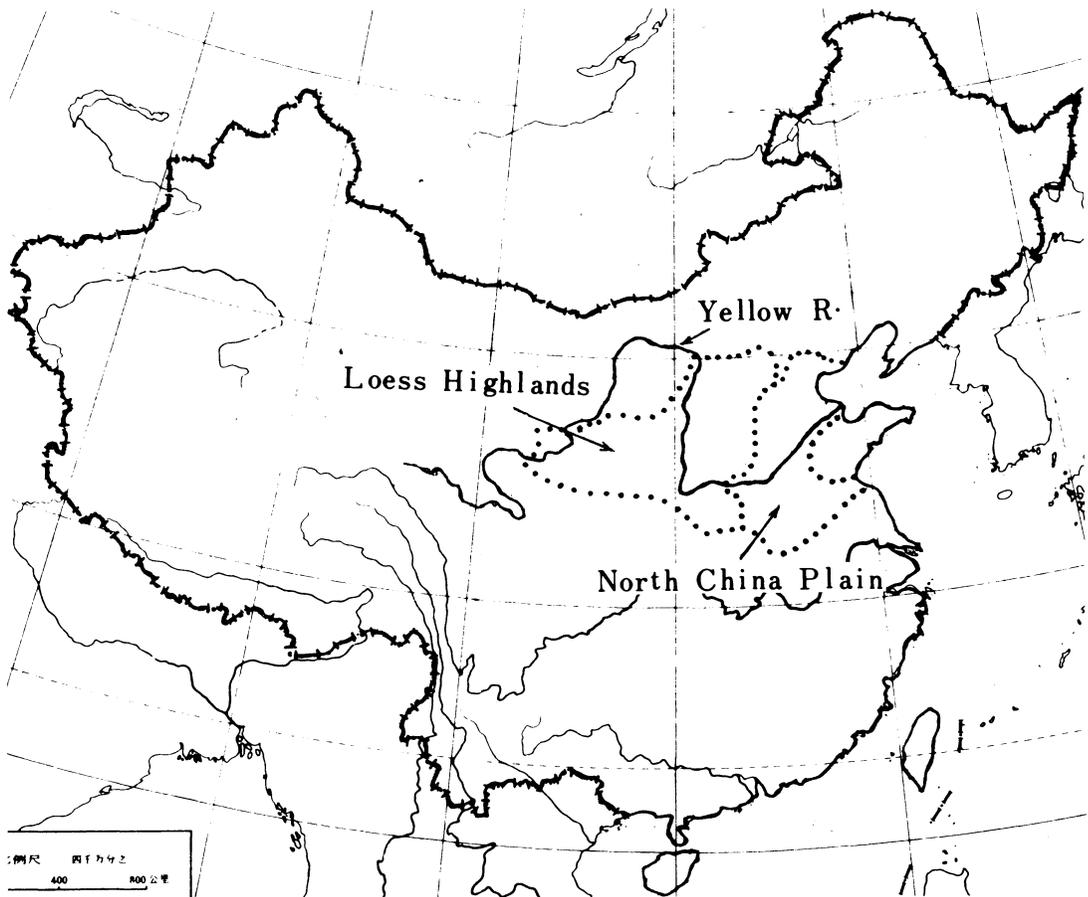


FIG. 1. Map of China showing area of study.

summer. Therefore, if the first useful summer rainfall of 20 to 30 mm comes too late, crop losses are certain to occur in response to soil moisture depletion below critical levels.

Since summer-planted crops consume less stored water before the onset of the first useful rains than do spring-planted crops, which in turn consume less than autumn-planted crops, the opportunity exists for cropping systems to be modified according to the specific soil-water regimes of the areas concerned. Although the amount of precipitation and its seasonal distribution vary widely from year to year, statistical analysis based on the existing climate record can be helpful. In considering such an analysis, it will be useful for the purposes of this discussion to employ what N. J. Rosenberg has identified as the "banking" procedure in treating irrigation scheduling.¹

Because application of Rosenberg's "banking" procedure requires information on the hydrological properties of the soil as well as some weather and crop data, we need to touch upon the main soil features of the area. Over 85 percent of the Loess Highlands is covered with a blanket of loess, an unconsolidated silty loam, generally 50 to 200 m thick. The North China Plain is the result of erosional deposits from the Loess Highlands and, therefore, is mainly composed of redeposited loess. Loess and redeposited loess are alike in their edaphic properties. The saturation permeability is commonly not lower than 500 mm a day, and typical field capacity is about 24 percent by weight. More often than not, cultivation induces deterioration of the physical structure of the soil, notably the formation at a depth of 15 to 20 cm of compacted subsoil that is impermeable to water, air, and plant roots, and the formation after each moderate or heavy rainfall of surface crust that restricts water infiltration. Both of these features drastically reduce the capacity of the soil to act as a water reservoir.

On well-managed soils with little deterioration under cultivation for tens of centuries, winter wheat may grow well and give high

yields in a long dry season by extracting water from ample soil storage, even when other fields in the same general area suffer heavy crop losses. Experiments conducted in the early 1960s in central Shaanxi Province by the Institute of Soil and Water Conservation of the Chinese Academy of Sciences found that, during a spring of unusually low precipitation, winter wheat drew water from a zone one to two meters below the soil surface.² On the experimental site, the soil had been kept in good physical condition and the water table was several tens of meters below the surface. Thus, upward movement of groundwater into the root zone could not have been significant. Improvement of soil hydrological properties by mechanical means to permit the root-zone to be replenished will increase the percentage of precipitation captured for crop production. This is a fundamental way of minimizing the effects of drought.

With the foregoing in mind, assuming soils with no surface crust or compacted subsoil and with a field capacity of 24 percent by weight, calculations made according to the "banking" procedure have generated encouraging results.³ For Yanan, in the middle part of the Loess Highlands, there is no noticeable water stress for summer-planted millet on an improved loessial soil over 80 percent of the years under study. However, drought would seriously affect spring-planted corn in most years and winter wheat in all years. For Taizai, a short distance to the west of the eastern boundary of the Loess Highlands, spring-planted corn is not short of water on an ameliorated soil in 90 percent of the years considered, although soil moisture conditions are never good enough for winter wheat.

Care has been taken to err on the conservative side of this analysis, but in long-range planning terms it seems fairly safe to predict that soil manipulation to maximize the utilization of precipitation in situ and the adoption of cropping systems adapted to the newly established soil moisture regimes will achieve the goals of drought mitigation. Rosenberg has reviewed a number of technologies useful for

minimizing the impact of drought. In addition to those considered above, one can include such measures as the establishment of windbreaks and shelterbelts, water harvesting, strip-cropping, crop selection, and use of crop residues and other mulches on soil surfaces—all of which are already sporadically employed in North China. Similarly, among other measures, the use of reflectants and selection for efficient water use may also prove pertinent to our case. With these additional measures in mind, there is an even greater margin of safety for the analysis presented here.

Taking into account the areal differences in the moisture regimes of the North China Plain and Loess Highlands, scientists have developed for this region a classification system based on soil and climate characteristics. The system enables farmers to determine where an improved soil moisture regime will be suitable for summer-planted millet only, for both summer-planted millet and spring-planted corn, or for those two crops and winter wheat. Such a classification scheme should prove useful for long-range planning purposes.

Within the boundaries of the Loess Highlands, the hills, tablelands, and plateaus are areas where the source of water, whether surface or underground, is negligible, and where the topography and engineering properties of the loess preclude any possibility for constructing nonerodible channels for water conveyance. Agricultural production arises solely from rain-fed farming. Hence, the minimization of the impact of drought can here be accomplished only by maximizing the use of precipitation in situ. Over the North China Plain and in the valleys and basins of the Loess Highlands, about half of the cultivated area is irrigated. However, there is almost no further opportunity to draw water either from surface or underground sources. Indeed, in recent years, water shortages have become acute, partly as a consequence of increased competition from urban and industrial users. The urgency of the situation is made all the more severe by the pollution of some water bodies. This situation is particularly serious in that

part of the North China Plain north of the Yellow River, where the depletion of aquifers has been reported in a number of areas. In effect, dramatic quantities of water are being requested by planning agencies of different levels for agricultural, industrial, and urban uses, but little attention is given to the overall limitation of water resources. And the gap between demand and supply is widening.

Nevertheless, after a look at the picture from the ground up, there is no reason to be utterly pessimistic. At present, some 90 percent of the water resources are allocated to agricultural uses, and agriculture is itself an inefficient user of water. Under existing water management regulations, the cost of water to the agricultural sector is very low. Generally, too much water is applied in irrigation. Not only is a scarce resource wasted, but also soil nitrogen is being lost at an accelerated rate both by leaching and by volatilization. The resulting poor aeration is itself unfavorable to crop growth. Indeed, a harmful but often neglected consequence of too heavy irrigation is the deterioration of soil structure, causing water logging and reduced aeration. A more conservative estimate is that an overall 20 percent reduction of water allocated to agricultural uses would present no difficulty to crop production. The water thus saved would be sufficient to expand water supplies to urban and industrial users by 180 percent. If water use efficiency can be achieved in industrial and urban consumption, and care is taken to consider water as a scarce and limited resource in planning industrial and urban development, the problem of water supply can be solved. Most probably, the gap between demand and supply can be filled eventually. The last resort is to convert some cultivated land now under irrigation to dry land farming. Scientists anticipate that crop yield after such conversion will not be lower than present yields but will actually be higher, if measures to maximize the use of precipitation in situ are carried out.

To be sure, various other solutions have also been proposed to resolve the water

shortages of the North China Plain. One of these is the possible transfer of water from the Yangtze River to areas north of the Yellow River. However, in addition to the fact that the capital expenditure for such a project would be huge and annual maintenance costs high, the amount of water that would be transferred when water shortages are greatest in the north would be small relative to actual demand. This project should be dropped if other remedies can be obtained by less expensive means.

At least one other measure requires mention here, namely the repair and redevelopment of the Yellow River silt regime. Over the Loess Highlands, soil erosion is the most serious in the world, contributing on average a sediment load to the Yellow River of about 1.6 billion tons annually. It is this sediment load that has given birth to the main body of the North China Plain, which is essentially a huge alluvial fan generated by the Yellow River and various smaller rivers descending from the Loess Highlands. Characteristic of a highly sediment-laden stream, the Yellow River has never ceased building up its channel, which is now three to ten meters above the surrounding countryside and confined by embankments that have been growing in place for at least twenty centuries. Between 602 B.C. and A.D. 1947, there are records of twenty-six major shifts in the course of the Yellow River and more than fifteen hundred floods. With each of these events, not only were large areas submerged but also wide tracts of land were buried under tons of silt and sand. In the last thirty-five years, the river has been safely kept within its embankments. However, recent records have shown that deposits in the channel of the lower Yellow River amount to 400 million tons per year, and containment of the river has come only as a stupendous engineering feat, with the threat of inundation increasing through time. Indeed, along with siltation and the deterioration of the channel, the riverbed is raised 10 cm each year. Simply stated, embankment strengthening alone is doomed to failure in the race against channel

siltation. Should the river break at its most dangerous locality, the resulting flood would directly affect an area with more than 150 million inhabitants. The only dependable remedy for this problem is soil conservation on the Loess Highlands, for if the lower Yellow River is not so heavily sediment-laden, our engineers can easily grapple with the problem of river control.

Since 80 percent of the sediment load delivered to the lower Yellow River stems from one-third of the drainage area of the middle Yellow River on the Loess Highlands, successful soil conservation in this key area alone will render the Yellow River much more easy to tame. According to weather records, during the last twenty to thirty years the maximum daily precipitation in this area has been only 100 mm. This is barely one-fifth of the saturation permeability of the loess. If soil surface crust can be eliminated and compacted soil modified, the rate of steady infiltration will greatly surpass the rainfall intensity on a daily basis.

Even if instantaneous rainfall intensity exceeds steady infiltration, terracing can serve as a final guard. Construction of terraces is a traditional practice of local farmers, and in the last thirty years improved construction methods have made terracing an even more effective measure. As recommended by the Yellow River Conservancy Commission, the elevated earth embankment on the outer rim of a terrace should be 20 cm high above the surface of the terrace. In this area, however, a height of only 5 cm is probably sufficient. To retain rainfall on a field is also to conserve the soil. Increased crop yield and decreased sediment yield may both result from maximizing the utilization of precipitation on the cultivated area.

Uncultivated land in this area is devoid of vegetation because hungry goats and fuel gatherers have ruthlessly destroyed the cover. Therefore this land is subject to unusually severe water-induced erosion. However, experimentation over five years in the vicinity of Yanan suggests that, once protected from

destruction, vegetation cover can be reestablished quickly by seeding a perennial legume from the air.⁴ When the vegetation is in good condition, its roots can draw water from as deep as 6 to 7 m. One solution to this problem is to seed with perennials that have a long dormant period or with annuals that have a short life cycle. However, protection of the vegetation is very difficult when crop productivity is as low as that now existing. Increasing crop yield by making the most of precipitation to provide more feed and fuel is essential to the success of soil conservation on such uncultivated land. With successful water and soil conservation on the interfluves, gulley erosion will be weakened correspondingly. The conclusion is that the sediment load of the middle and lower Yellow River can be greatly reduced.

Over the North China Plain there seems to be an eleven-year cycle of variation in annual precipitation. Recent analysis has revealed that the overall agricultural production in drier years is better than in wetter years for a number of reasons. About half of the cultivated land is irrigated. Too much rain in certain phenological periods is unfavorable to cotton production. Salt accumulation in the topsoil due to the capillary rise and evaporation of water from the elevated water table in spring is harmful to wheat. Large areas become water-logged and salinated. Even during a dry spell, poor drainage and soil salinization are no small causes of low agricultural production. If farmers of the North China Plain and Loess Highlands take appropriate steps to store for future use precipitation as it falls, the excess accumulation of water and salt in depressed areas will be reduced, and it will be much easier to alleviate the problems by drainage, leaching, and other means.

The foregoing analysis emphasizes measures to maximize the use of precipitation in situ as an answer to the problem of drought in North China. As information now available shows, the same steps will also help resolve other major problems related to river conservancy, agriculture, and water supply. But the necessary technologies and the improvement

of relevant technologies require further research. Technology itself is useless, unless it is economical, feasible, available, and acceptable to the farmers. The investigation of these factors is also required. For the sake of brevity, only a short accounting of the four most important topics of study on the physico-biological aspects of the problem need be noted here. These are:

1. The development of methods for predicting with reasonable accuracy the infiltration, deep percolation, and evapotranspiration applicable to North China. Extensive studies have been conducted on this topic all over the world, but there are still a great number of unknowns. Although it is necessary to provide local or regional calibration in order to transfer useful findings from abroad and thereby fill the gaps in our knowledge, very little experimental research has ever been conducted on this question in North China.

2. Experimental studies of methods for modifying soil physical properties to accommodate rain as much as possible. Eradication of surface crust and loosening of compacted subsoil can be accomplished only by mechanical means on the soils of North China, which commonly have an organic content of less than one percent. In some localities, the traditional practice is simply to scrape off the soil surface crust. It is the perception of the farmers that there is "water and fire with the plow" (i.e., water and temperature are increased by manipulation of the soil through plowing). Much the same is said of deep tillage. However the operation may be performed, it gives rise to an array of short-term and long-term consequences, and is in any case laborious and costly. Such mechanical manipulations repeated year after year may do more harm than good. Yet, recent reports indicate that increased crop yields during the early years of mechanical manipulation supply additional organic matter, thereby improving

soil structure. In any case, more efficient implements and better management are certainly of great importance here. And, for our purposes, a unified research program aimed at discovering the principal factors relevant to the different environments of North China is clearly needed.

3. Cropping systems adapted to the improved soil moisture regime in the context of the environment of North China.

4. Optimum fertilization for the recommended cropping system.

In short, to take full advantage of an improved soil moisture regime, suitable cropping and nutrient supply systems must also be implemented. Decision-making on these should be supported by experimental research. And, although these four topics do not represent an exhaustive list of necessary investigations, they are essential to the search for cheaper and quicker solutions to the problem of drought in North China.

NOTES

1. Norman J. Rosenberg, "Adaptations to Adversity: Agriculture, Climate, and the Great Plains of North America," *Great Plains Quarterly* 6 (Summer 1986): 202-17.

2. Verbal communication to the author from Li Yushan. See also Li Yushan, "The Function and Effect of Soil Reservoir," *Bulletin of Soil and Water Conservation* (no. 5 1983): 27-30 (in Chinese).

3. Author's unpublished findings from field studies and analyses of experimental data from 1953 to 1980. See also Huang Bingwei, "Some Problems of Soil Conservation in the Drainage Area of the Middle Yellow River," *Proceedings of the Symposium on Land Amelioration in China 1982* (Beijing: Science Press, 1983), pp. 94-103 (in Chinese) and Huang Bingwei, "Professor Chu Ko-chen and Geographical Research on Agriculture with Special Reference to North China," *Acta Geographica Sinica* 39 (1984): 1-10 (in Chinese with lengthy English summary).

4. Liang Yimin, Li Daiqiong, Cong Xinhai, and Wang Youko, "Bring about a Virtuous Circle," *Bulletin of Soil and Water Conservation* (no. 6 1983): 28-33 (in Chinese).