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# Research on Classification of Land Consolidation Project Zones in Inner Mongolia

MENG De-biao\*, ZHU Dao-lin

College of Resources and Environmental Sciences, China Agricultural University, Beijing 100193, China

**Abstract** Taking Inner Mongolia as the research object, from natural conditions, socio-economic conditions, land use conditions and so on, we select 8 indices that impact the land consolidation project, namely climate, topography, soil type, water resources conditions, farmland amount per capita, the degree of agricultural mechanization, the status of irrigation guarantee and land consolidation potential, so as to establish rational index system of project zoning. By using cluster analysis method, we divide Inner Mongolia into 5 different types of project zone, namely multiple-purpose project zone of the western Greater Khingan Mountains, irrigation project zone of Nenjiang and the western Liao River plain, the central dry farming complementary irrigation project zone, Hetao Plain and Huanghe River irrigation project zone, and the western oasis irrigation project zone. This paper analyzes the natural conditions of all regions and constraint factors of agricultural production, and establishes the corresponding project design model, in order to provide reference for the land consolidation project design in Inner Mongolia and even other similar regions.

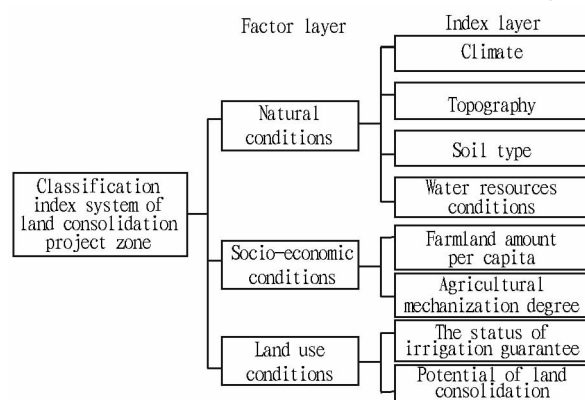
**Key words** Land consolidation, Zone, Inner Mongolia, China

Land consolidation project zone, the type of branch of geographical classification, is defined according to the construction objective, regional characteristics, project content, and consistency principle of project combination of land consolidation<sup>[1]</sup>, which is a unit reflecting characteristics of regional difference and project combination of land consolidation. Land consolidation project zone is the comprehensive zone determined after integrating geographical environment factors, socio-economic factors, land use zoning, classification of agricultural zones and administrative division and so on. The classification of land consolidation project zone can provide reference for researching the design model of land consolidation project zone, standard revision of regional land consolidation project and special planning of land reclamation. Inner Mongolia is the biggest provincial administrative area spanning the biggest longitude in China, and one of 13 major grain-producing provinces in China. The vast territory of Inner Mongolia causes the enormous differences within in terms of natural conditions, socio-economic conditions, land use conditions and so on<sup>[2]</sup>, and determines the regional difference of design of land consolidation in Inner Mongolia. Conducting the research on land consolidation project zone in Inner Mongolia, will be conducive to strengthening the rationality and practicability of design of land management project in Inner Mongolia, and providing reference for setting up design model of zoning of land consolidation project in other regions of China, so as to promote the sustainable development of land consolidation cause.

## 1 Index selection and research method

**1.1 Index selection** We conform to the principles of difference, completeness, irreplaceability, and operability, and se-

lect 8 indices in order to conduct analysis, in terms of nature, socio-economy and land use, which can be seen in Fig. 1.



**Fig. 1 The index system of type classification of land consolidation project zones**

Among them, climate refers to the average conditions, characteristics and variation regularities of weather of many years in one place or region, which determines agricultural farming system and varieties of crops in land consolidation zone; topography and landscape refer to the undulating and rugged state of ground, which affects the shape and size of farmland, and selection of irrigation methods; soil, a layer of loose material that can keep plants growing, is composed of a variety of granular minerals, organic matter, moisture, air, microbes and so on, on the surface of the earth, which has a direct impact on human activities in agricultural production, different soils with different fertility; water resources are the general term of atmospheric precipitation, surface water and groundwater that can be used by human under certain technical conditions, which affects the reasonable arrangement of agricultural structure and selection of irrigation methods; the amount of farmland per capita refers to the ratio of farmland area and agri-

cultural population in all counties and banners, which reflects the correlation between population and farmland, and explains the scarcity of farmland resources<sup>[3]</sup>; agricultural mechanization degree refers to the ratio of total power of agricultural machinery and number of rural households in all counties and banners, which reflects the practical role of agricultural machinery in the production of farming; irrigation guarantee status refers to the proportion of effective irrigation area (irrigated land) in the total area of farmland, which is used to explain the extent of artificial irrigation of farmland, and farmland irrigation degree<sup>[4]</sup>, and reflects the capacity for resisting natural disasters; land consolidation potential means that by land consolidation, we transform the reserve resources into farmland in the region, which reflects the supply amount of reserve resources that can be transformed into farmland.

**1.2 Research method** The land consolidation project zoning is usually carried out on the basis of many indices. The values of different indices have different units and dimensions, which will have an impact on the accuracy of classification results<sup>[5]</sup>. Therefore, prior to the analysis, we should conduct non-dimensional processing on the value of all indices.

$$Y = (X - X_{\min}) / (X_{\max} - X_{\min}) \quad (1)$$

Y-the assessment value of quantitative index; X-actual value of dimensional index;  $X_{\max}$ -maximum value of dimensional index;  $X_{\min}$ -minimum value of dimensional index. We adopt the way of assigning value to process topography, soil, hydrology and so on, according to region. We use Euclidean distance to process the elements, and the calculation formula is as follows:

$$d_{ij}(2) = \left( \sum_{k=1}^p |X_{ik} - X_{jk}|^2 \right)^{1/2} \quad (2)$$

We use cluster analysis method to classify the project zones, view n variables to be clustered as one type respectively, and calculate the cluster statistic between two types, namely distance or similarity coefficient. We combine two types with the closest relationship into one new type, until finally all of the variables are classified as one type, by parity of reasoning. After the completion of cluster analysis, we reuse ArcGIS 9.2 software to conduct spatial overlapping analysis on the clustering results and administrative map of Inner Mongolia. In the process of overlapping processing, given that the characteristic of administrative management of current land consolidation project is to take counties, cities, and districts as units for organizing and management of project, so the initial zoning result will be adjusted according to the principle of relatively continuous distribution of geographical space and the principle of relatively intact administrative boundary of banners (counties, cities and districts). As for the banners and counties spanning different zones in initial result, according to the size of spanning zones, we regard the district, which has the biggest area, as the final regional zoning result, thus we get the classification result of land consolidation project zones.

## 2 Results and analysis

**2.1 Results of classification of zones** According to the relevant classification principles of land consolidation project zones, by using the aforesaid zoning method of cluster analy-

sis, we divide Inner Mongolia into five project zones, which can be seen in Fig. 2. They are as follows: the multiple-purpose project zone of the western Greater Khingan Mountains; the irrigation project zone of Nenjiang and the western Liao River plain; the central dry farming complementary irrigation project zone; Hetao Plain and Huanghe River irrigation project zone; the western oasis irrigation project zone.

### 2.2 Design model of all project zones

(1) The multiple-purpose project zone of the western Greater Khingan Mountains.

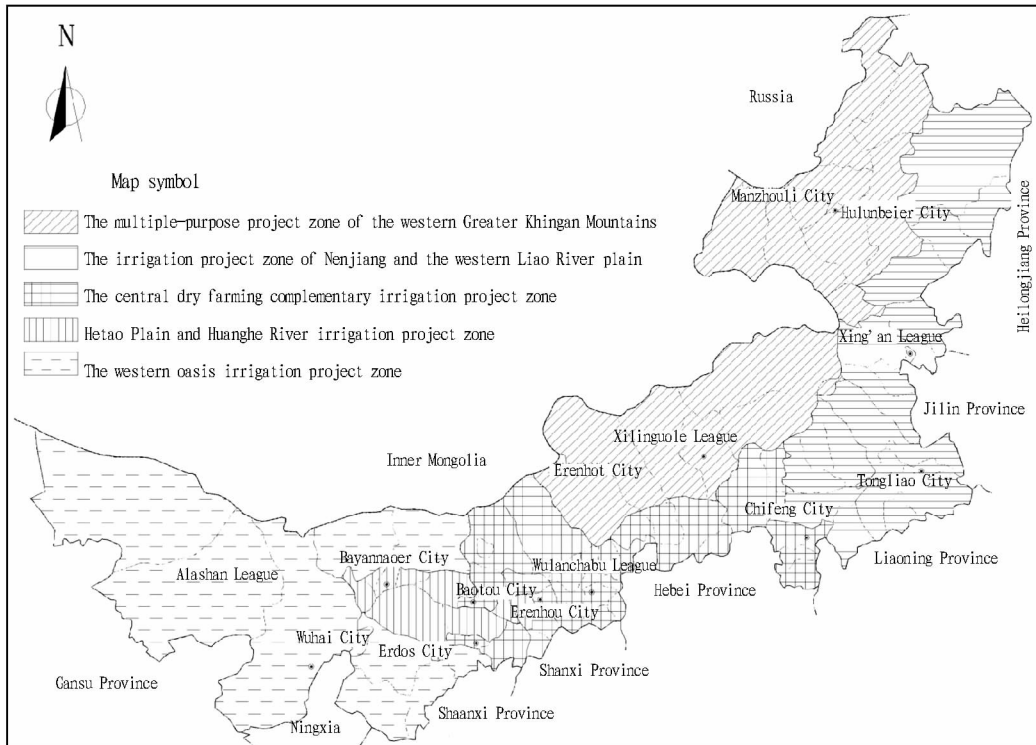
This region, located in the west Hulun Buir City of eastern Inner Mongolia and Greater Khingan Mountains, the north pasturing area of Xilinguole League, the west Xing'an League and Tongliao City, includes 18 banners (counties and cities). The topography is plain or basin, with gently undulating terrain; influenced by relatively high latitude, the climate is relatively cold. The annual average temperature in this region is  $-4 - 0$  °C; the annual accumulated temperature ( $\geq 10$  °C) is 1 600 - 2 600 °C; the sunshine hours are 2 900 - 3 100 h; the frost-free period is 80 - 120 d; the rain mainly concentrates in summer and fall; the total rainfall ranges from 200 to 400 mm; the amount of evaporation is between 1 600 and 1 800 mm<sup>[6]</sup>. The conditions of regional water resources are good, especially the groundwater resources are relatively abundant, but the exploitation and use rate is low<sup>[7]</sup>. The major soil type in this region is chernozem soil and chestnut soil, and the chernozem soil is mainly in the western foot of Greater Khingan Mountains and Hulun Buir City. The soil is fertile and the soil suitability is wide. The constraint factors of agricultural production in this region include low temperature, drought, high winds and other natural disasters. In addition, the inputs of agricultural infrastructure construction are not enough, especially the establishment of farmland irrigation, so the capacity for resisting natural disasters is low.

In the design of regional land consolidation project, the shape of farmland is mainly the large-strip farmland. Given that the terrain is flat or the terrain is gentle-slope shape, so it is unnecessary to carry out large-scale land consolidation project, and it only needs regional consolidation. As for the method of regional consolidation, in general, we use inclined plane method, that is, in accordance with certain degree of slope, we conduct consolidation on the undulating and rugged terrain<sup>[8-9]</sup>, so as to meet the need of continuous operation and production of agricultural production machinery. The water conservancy of farmland is mainly the construction irrigation facility. The water projects in the area near the river mostly use pump station to pump water from the surface of ground for irrigation, and the arable land far away from the river adopts motor-pumped well for irrigation.

The field irrigation projects mainly adopt sprinkling irrigation and low-pressure pipe irrigation, and medium-sized farms and large farms often adopt various types of sprinkling machines, such as lateral-moving-type, rolling-type, pointer-type, reel-type and so on. Most of the small farms and family farms mainly adopt semi-fixed sprinkling irrigation and low-pressure pipe irrigation. Considering the limited rainfall, the drainage projects

have not high demand for drainage, so the establishment density of drainage ditch is small, and part of the ramp-like plains even do not set up drainage ditch, in order to preclude the role of drainage ditch in converging the runoff and avoid the erosion of the surface of earth. The supporting power line is set up along the road or shelterbelts, so that it doesn't affect the passing of production machinery in the farmland. The field road projects, mainly set up field road, one level, and the field road projects do not set up production road, in order to ensure the passing of the large agricultural production machinery. The field

road can also be divided into two types, namely first-level field road and second-level field road: the first-level field road sets up 6–8 m breadth; the second-level field road sets up 4–6 m breadth. The road is paved with mix of mud and gravel, and the spacing of field road is set up as above 1 000 m. The farmland protection projects are mainly to grow the farmland shelterbelt, which is set up along the strip-like farmland, adjacent to the field road. The growing breadth widely adopts 4–6 lines, and as for the varieties of tree, the varieties of tree suitable for the local area are planted.



**Fig.2 The land consolidation project zones of Inner Mongolia**

(2) The irrigation project zone of Nenjiang and the western Liao River plain.

This region, located in the plain on the right of bank of Nenjiang River and river basin of the west Liaohe Plain, includes a total of 21 banners (counties, cities), such as the east Hulun Buir City, Xing'an League, Tongliao City, and Chifeng City. The topography in this region is mainly the plain, including a small area of mountain, hilly and sandy. The climate in the irrigation project zone of Nenjiang and the western Liao River plain is the continental climate of the northern temperate zone, which has relatively even rainfall, ranging from 400 to 450 mm. The annual average temperature in this region is  $-2 - 5^{\circ}\text{C}$ ; the annual accumulated temperature ( $\geq 10^{\circ}\text{C}$ ) is 1 600–3 100  $^{\circ}\text{C}$ ; the sunshine hours are 1 600–3 100 h; the frost-free period is 85–140 d. The major soil type in this region is chestnut soil, meadow soil, and chernozem soil. Apart from a small fraction of regions in the south, the soil in most parts of this region is fertile. The limiting factors of agricultural production are as follows: the rainfall in spring within the region is short, so the problem of spring drought is serious; in some are-

as, the problems of desertification of land, soil erosion and environmental degradation, arising from excessive reclamation, are becoming increasingly serious.

In the design of regional land consolidation project, the shape of farmland is mainly the strip-like farmland. Influenced by the topography, the length of strip-like farmland is 400–800 m and the breadth of strip-like farmland is 200–400 m. As for the method of regional consolidation, in general, we use planar method to conduct consolidation on the undulating and rugged terrain, so that the surface of strip-like farmland is fair, to meet the need for irrigation of farmland plots. In the farmland water conservancy projects, the water projects in a small quantity of areas near the river use pump station to pump water from the surface of ground for irrigation, and the arable land in most of the areas mainly adopts motor-pumped well for water supply and irrigation. The field irrigation projects mainly adopt open channel and low-pressure pipe irrigation. In the areas which use motor-pumped well for water supply, it mainly adopts low-pressure pipe irrigation, while the farmland in the areas that use surface water for irrigation, mainly chooses the open chan-

nel for irrigation. The drainage works system is complete and the way is mainly the self-drainage on the basis of the natural terrain. The field road projects, mainly set up two levels: field road and production road. The field road sets up 4 – 6 m breadth, and the road is paved with mix of mud and gravel; the production road sets up 2 – 3 m breadth, and the road is pure soil and mud. Some production roads with the breadth equal to 3 m, choose to be paved with mix of mud and gravel. The spacing of field road is set up as 800 – 1 000 m, and the spacing of production road is set up as 300 – 500 m. The farmland protection projects are mainly to grow the farmland shelterbelt, which is set up along the roads in the field and the periphery of linear ground objects. The growing breadth widely adopts 2 – 4 lines, and as for the varieties of tree, the varieties of tree suitable for the local area are planted. At the same time, we should pay attention to strengthening the monitoring and prevention of land degradation.

(3) The central dry farming complementary irrigation project zone.

This region, located in the northern hilly area of Yanshan Mountain, the north of Yinshan Mountains, Wulanchabu Plateau and hilly region, and the edge of loess hilly area, includes 40 banners and counties, such as Chifeng City, Xilinguole League, Wulanchabu City, Huhehaote Municipality, Baotou City, Erdos City and so on. The altitude in the region is 1 000 – 1 600 m, with complex terrain. The landform type includes low mountains, hills, mesas, valleys, basins, and so on. There is a great difference of the distribution of water and heat in the region. The annual average temperature in this region is 4 – 6 °C; the annual accumulated temperature ( $\geq 10$  °C) is 2 000 – 3 000 °C; the sunshine hours are 2 800 – 3 100 h; the frost-free period is 120 – 140 d; the precipitation is 250 – 400 mm, with uneven distribution in terms of region and season. The major soil type in this region is chestnut soil, aeolian sandy soil, chestnut cinnamon soil, gray cinnamonic soil and so on. The limiting factors of agricultural production are as follows: the seasonal rainfall distribution is uneven, and the problem of spring drought is serious, resulting in the low yield of farmland; the agricultural infrastructure is short or damaged seriously; there is concentrated and intense rainfall in summer and fall, easily leading to soil erosion.

In the design of regional land consolidation project, the shape of farmland is mainly terrace or ridge-bordered plot, wherein the transformation of sloped farmland into terrace is the core of land consolidation project. As for the method of regional consolidation, in general, we use planar method to conduct consolidation, so as to realize the internal consolidation of plots ultimately, to meet the need of irrigation. The length and the width of terraces, influenced by terrain, are uneven. In the farmland water conservancy projects, the irrigation water source is mainly the groundwater, therefore the water projects are mainly to dig well or construct water-storage and rainwater-harvesting facilities. The field irrigation projects mainly adopt low-pressure pipe irrigation, and some areas with good economic conditions and high-level management, adopt the water-

saving way of sprinkler irrigation. The drainage works system is complete and the way is mainly the self-drainage on the basis of the natural terrain. The supporting power facilities are based on the location of motor-pumped wells, and the power lines can be connected inside in the project zone or adjacent zones. The field road projects, mainly set up two levels: field road and production road. The field road sets up 4 m breadth, and the road is paved with mix of mud and gravel; the production road sets up 2 m breadth, and the road is pure soil and mud. The spacing of field road is set up as 800 m, and the spacing of production road is set up as 300 m. The spacing of some terrace areas is even smaller. The farmland protection projects include farmland shelterbelt and forest for soil and water conservation. The farmland shelterbelt is set up within the roads in the field and the field, which is used to prevent the disaster of wind. The growing breadth widely adopts 2 lines. The forest for soil and water conservation is aimed at strengthening conservation of water and soil. The forest for soil and water conservation is often grown in the gulch where the soil erosion easily occurs. The growing lines will be different along with the different situations of soil erosion. As for the varieties of tree, the varieties of tree suitable for the local area are planted.

(4) Hetao Plain and Huanghe River irrigation project zone.

This region, located in alluvial-proluvial fan in front of Yin Mountains, Huanghe River Hetao Plain, and Dahei River Alluvial Plain, includes 10 banners and counties, such as Bayannaoer City, Ordos City, Baotou City, Hohhot City and so on. The topography of Hetao Plain and Huanghe River irrigation project zone is flat. The annual average temperature in this region is 6 – 8 °C; the annual accumulated temperature ( $\geq 10$  °C) is 2 000 – 3 200 °C; the sunshine hours are 2 800 – 3 300 h; the frost-free period is 130 – 140 d; the precipitation in this region is about 300 mm. The ample sunshine and radiation provide favorable light and heat conditions for the agricultural production. The major soil type in this region is chestnut soil, and brown soil. The limiting factors of agricultural production are as follows: the irrigation facilities are out of fashion, and the canal system in some areas is disorderly; the fair ground causes the poor drainage system; in addition, the way of flood irrigation gradually raises the water table, resulting in the phenomenon of secondary salinization.

In the design of regional land consolidation project, the shape of farmland is mainly the small-strip farmland. Influenced by the topography, the length of strip-like farmland is 300 – 600 m and the breadth of strip-like farmland is 100 – 300 m. The land consolidation project is mainly to conduct the consolidation on the undulating parts in the fields. In addition, there are always sand mounds within the farmland, so in the process of consolidation, the project of outward transport for spoil is needed. In the farmland water conservancy projects, the water source is mainly the water of Huanghe River. The field irrigation projects mainly adopt open channel, wherein the three-level channel is built by concrete, last-level channel adopts earth canal, and the channel at all levels adopts gravity irrigation. The way of drainage is mainly the open ditch drainage, and the

depth standard of ditches should meet the need of reducing salinization. The areas with serious salinization can adopt motor-pumped well to drain and reduce the water table. The supporting constructions of canal system include sluice gate at all levels, bridges and culverts and so on, which play a role in controlling irrigation. The field road projects, mainly set up two levels: field road and production road. The field road sets up 4 m breadth, and the road is paved with mix of mud and gravel; the production road sets up 2 m breadth, which is often set up at the side of last-level channels, in order to conduce to passing and maintenance of channels. The spacing of field road is set up as 600 – 800 m, and the spacing of production road is often different, on the basis of the establishment of canal system. The farmland protection projects are mainly to grow the farmland shelterbelt, and forests for windbreak and sand-fixation. The farmland shelterbelt is set up along the roads in the field and the periphery of ground objects of channels. The growing breadth widely adopts 2 – 4 lines; the forests for windbreak and sand-fixation are often grown in the edge of sands or the periphery of sand heap. The planting way is the combination of arbor and shrub, wherein the planting lines of arbor is 6 – 10 lines.

(5) The western oasis irrigation project zone.

This region, located in the west Inner Mongolia, Alashan Plateau areas, includes 12 banners and counties, such as Alashan League, Bayannaer City, Erdos City, Wuhai City and so on. The topography in this region mainly includes plain, mountain, hilly, desert, and so on; the climate is dry continental climate of northern temperate zone, with prominent characteristics of the climate of four seasons, namely drought and little rainfall, drastic wind and considerable sand, and great day-and-night temperature difference. The precipitation is 40 – 250 mm and the evaporation is 2 400 – 4 200 mm; the annual average temperature in this region is 6 – 8 °C; the annual accumulated temperature ( $\geq 10$  °C) is 2 800 – 3 600 °C; the sunshine hours are 2 900 – 3 400 h; the frost-free period is 110 – 160 d. The major soil type in this region is grey desert soil, grey-brown desert soil, brown soil, aeolian sandy soil and so on. The limiting factors of agricultural production are as follows: the climate is dry; the rainfall is short; groundwater resources are scarce; the natural ecological environment is poor.

In the design of regional land consolidation project, the shape of farmland is mainly the small-strip farmland. Influenced by the topography, the length of strip-like farmland is 200 – 400 m and the breadth of strip-like farmland is 100 – 200 m. As for the method of regional consolidation, in general, we use planar method to conduct cut-and-fill consolidation on the undulating and rugged terrain. In the farmland water conservancy projects, given that most of the farmland is at valley or other oases, so the water projects are to use the surface water in the valley or motor-pumped well to pump groundwater for irrigation. The field irrigation projects mainly adopt open channel and low-pressure pipe irrigation. The open channel adopts lined canal and often takes advantage of the topography for gravity irriga-

tion; in the areas which use motor-pumped well for water supply, it mainly adopts low-pressure pipe irrigation. Due to the limited rainfall in this area, so we have no need to set the drainage system. The field road projects, mainly set up two levels: field road and production road. The field road sets up 4 m breadth, but influenced by the surface soil texture, there is a need to set sand-gravel cushion in order to promote the bearing capacity, and the road is paved with mix of mud and gravel; the production road sets up 2 m breadth, and the road is pure soil and mud, but the number of settings is small. The farmland protection projects are mainly to grow the farmland shelterbelt, which is set up along the roads in the field and the periphery of linear ground objects. The growing breadth widely adopts 2 – 4 lines, and as for the varieties of tree, the varieties of tree suitable for the local area are planted.

### 3 Conclusion

By using cluster analysis method, we divide Inner Mongolia into 5 different types of project zone, namely multiple-purpose project zone of the western Greater Khingan Mountains, irrigation project zone of Nenjiang and the western Liao River plain, the central dry farming complementary irrigation project zone, Hetao Plain and Huanghe River irrigation project zone, and the western oasis irrigation project zone. In land use and management, we should adopt the corresponding project design models, according to the limiting factors existing in the agricultural production in different project zones.

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