AN APPROACH TO THE THEORY OF AGROECOLOGICAL ENVIRONMENTAL SUITABILITY AND ITS APPLICATION*

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Abstract

This paper sets forward the theory of agroecological environmental suitability degree and has set up models by fuzzy mathematics on basis of modern ecological theory. As an example of the Gansu's Loess Plateau ared is analyzed by the authors. The analysis and resulns of calculation provide a scientific basis for agricultural production overall arrangement in Gansu's Loess Plateau area. The theory and models can be used in other area.

Key words approach; theory of agroecological environmental; application

中图分类号 S18; O159

0 Introduction

Agroecological environment refers to the nonbiological environment of an agroecological economic system. It is the important base that four basic functions of agroecological economic system (material circulation, energy mobility, information tranmission and value multiplication) are realized and the basis by which agricultural production is advanced. A agricultural production is made in a specific ecological environment and is effected and restricted by it. These relationships are especially intense for arid land agriculture. Therefore this approach to the agroecological environment suitability degree has both important theoretical and practical significance for agricultural production, especially in arid or semiarid area.

1 Niche and Its Measurement

Niche theory is one of the basic theories in modern ecology which reveals the relationship between organisms and their environment (generalized environment). What this theory leads to in the study of ecological environments is the value of quantitative analysis. Before introduction the theory, it is necessary to analyze all ecological factors in an agroecological environment briefly and than lead into the concept of agroecological space.

1.1 *Agroecological Factors and Agroecological Space*

Crops are the major utilized objects of agricultural production and an important part of life system in agroecological system. Many physicai factors effect the course of crop growth and development.

* 本文于1991年3月4日收到

These factors are called crop ecolgical factors. Since crops are the major product of an agroecolgical economic system, they also can be called agroecolgical factors or component of agroecological economic system.

Every ecological factor has its own natural attribute and has a different effect on crop growth respectively. The most common ecological factors include: climate, e.g. illumination, temperature and humidity; material circulating factors, e.g. moisture, carben dioxide (CO_2), nitrogen, phosphorus, etc., all kind of elements and microorganism; soil factors, e.g. soil type, soil moisture, fertility, etc.; topgraphic and geomorphologic factors, e.g. elevation, etc..

As for certain crop, there are n ecological factors concerned. They compose the environment of this particular crop. Vector.

$$X = \begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{pmatrix}$$

shows a certain environment state, i.e., a special envionment (where x_i is numerical value indicating number i ecological collection

$$A = \{X \mid X \in E^n\}$$

describe the agroecological environment of some terraced range, which is called crop's ecological space or agroecological space.

The study of ecological space, the trend of ecological facotrs and their effect on crops, can reveal motive laws of agroecological system and provide a scientific basis for agricultural economic activity.

1.2 Niche and its measurement

The term niche was first put forward by Grinnell in 1917[3], who defined niche as ultimate distributional unit of a species or subspecies; later animal ecologist Elton defined niche as the function role and position of organism in commmunity in 1927[2], In 1957, Hutchinson gave the concept niche a mathematical abstract description and thought that niche is hypervolumn in an n-dimensional resource space[6]. In the last on part few years, many animal ecologists and theoritical ecologists have said that niche and resouce utilization spectra have the same meaning[1], while some botanists regard niche as a general relationsni between plants and their enuironment[1]. The internal meaning of the proceding definitions lies in two aspects as follows: One is the general relation between an organism and its existing environmental condition; the other is the interspecies relationship in biological community. Therefore, if the dynamic relation between one species and others is regarded as the one between one species and its generalized environment (including nonorganisms and other species in a biological community), then the preceding definition can be united compietely, ie, niche is the relationship between one species and its generalized environment, which including the content from two aspects: one is its species requirement for generalized environment; the other is the effect on its species by generalized environment. based upon this premise, chinese scholars Wang Gang, et al[5], put forword a measurement formula of niche, ie. niche is the projective relationship indicating the attributive feature of one species from the ecological space a indicating the environment attribute to the non-negative numerical space R^+.

$$Y = f(x) \tag{1}$$

where $X \in A$ and $Y \in R$.

We learn from above analysis that niche theory is a powerful tool in studing the relationship between a certain crop species and its biological community, and its nonbiological enviroment. But it is also necessary to make some revisions to the niche concept in order to study the relationship between most of the crops and its environment. In the course of analysing the conditions of agricultural production, we must also evalate agricultural production, evalate agricultural ecological environment suitability degree for the crop's development environment, and set up its mathematical models.

2 Agroecological Environment Suitability Degree and Its Dynamic Process

The concept of niche is essentially one that reflects the general relationship between biological species and the ecological environment (generalized environment) composed of all kinds ecological factors, including the content from two aspects: one is the demands of biological species for all ecological factors, the other is the effect of the environment on this species. So Niche is the quantitative description of the relationship between a certain biological species or subspecies and their generalized environment, it is substantially a projection from the ecological space A indicating environmental attributes to the numerical collection R^+ indicating the attributes of the biological species.

From the upper analysis, we can define agroecological environment suitability degree as a kind of projective relation from the nonbiological ecological space indicating nonbiological environmental attributive feature to a numerical collcetion indicating attributive feature of most crops development (the increase of crop's organism) in order to study the relationship between most crops and there nonbiological environment, and describe the suitability degree of the crops in their nonbiological environment. In order to study the problem quantitatively, we set up the mathematical models describing agricaltural ecological environmrnt suitability degree and their dynamic process by using the method of fuzzy mathematics.

2.1 Ecological Factor Suitability

As far as the development of most crops is concerned, from seeding to harvesting is a continous course in a life viewpoint, though dried material accumulation is an interval and dispersion. In this course, the stages of emergence, jointing, heading, blossoming and fruiting have different demands for various ecological factor. In another aspect, every ecological factor has a quantitively changeable range indicating its unique attributes whether in time or space, this change is difficult to tally with the demands of the course of crop development. The term "ecological factor suitability" means the best-matching of every ecological factors during the process of most crop development. Therefore, the purpose of evaluating agroecological factor suitbility is to be able to transform the change of ecological factors, and its influnece on the growth speed of crop organism and the amount of crop's production.

In the process of matching crop development and each ecological factor, "high" and "low", "fast" and "slow", "superior" and "inferior" etc., all of which are "fuzzy" concepts too difficult to judge using only duality logic. So the ecological factor suitability should be described by fuzzy mathematics.

Let us suppose that the numerical range indicating attributive feature of a certain ecological factor r (ie. one-dimension ecological space) is $I = [a,b]$, thus the ecological factor suitability degree is a fuzzy subcollection determined as $[0,1]$ in I , it is.

$$\underset{\sim}{S}_r \subset [a,b] \tag{2}$$

$$S_T \triangleq \mu_{\underset{\sim}{S}_r}(R) \to [0,1] \tag{3}$$

where, $\underset{\sim}{S}_r$ is the fuzzy subcollection of the suitability degree of ecological factor r; $\mu_{\underset{\sim}{S}_r}(r)$ is subordinate function of $\underset{\sim}{S}_r$; S_r is the subordinate of ecological factor r to $\underset{\sim}{S}_r$. Every ecological factor has a definite relation to the increasement of the majority of crop organisms. According to this relationship, we can draw up the suitability degree subcollection of this ecological factor under other ecological factors condition, or set forward the subordinate function of its suitability, or plot its suitability degree curve (subordinate function curve). So, for every ecological factor, we can confirm the subordinate function of its suitability degree or draw its suitability degree curve by studying the relation of that factor and the increasement of majority crop organisms. But the course of crop development not only is effected by one ecological factor, but it is the result of the comprehensive action of many ecological factors. Eventually, it's necessary to study the suitability degree of crop development within the whole ecological space, ie. agroecological environment suitability degree.

2.2 *Agroecological Environment Suitability Degree*

In agroecological environment composed of many ecological factors, the comprehensive effect of all the factors in the course of crops development is not equal to the accumulation of the independent effect of every ecological factors. This is because every ecological factors has different attribtutes and effect on crops, and crops have various demands to every ecological factor. The agroecological environment suitability can't be replaced by the suitability of any single ecological factor. Let's suppose a n -dimension agroecological space contains n ecological factors $x_1, x_2, \cdots\cdots, x_n$ and each of them composes one-dimension ecological space $I_1, I_2, \cdots, I_n$ respectively. We learn from the preceding analysis that ecological factor $x_i (i = 1, 2, \cdots, n)$ has its own suitability degree subcollection $\underset{\sim}{S}_{x_i}$ for crops development. its subordinate function is:

$$S_{x_i} = \mu_{\underset{\sim}{S}x_i}(x_i) \tag{4}$$

Hence, we can set forward the agroecological environment suitability degree subcollection $\underset{\sim}{S}$, whose subordinate function is described as following:

$$S = \mu_{\underset{\sim}{S}x}(x) = \sum_{i=1}^{n} a_i \mu_{\underset{\sim}{S}_{x_i}}(x_i) \tag{5}$$

Where, $0 < a_i < 1$ $(i = 1, 2, \cdots, n)$ is the important value of every ecological factor, they satisfy $\sum_{i=1}^{n} a_i = 1$.

2.3 *The Dynamic Process of an Agroecological Environment*

The change of every ecological factors with time may be expressed as an annual periodic dynamic process by its suitability degree. For this, we can use the average state of a certain characteristic year (good year of bad year) or average state of many years to describe the the dynamic process of an agroecological environment.

As for a single ecological factor, such as temperature T, we may indicate its change over time by the function $T(t)$. $T(t)$ is a continuous course or dispersed one. As far as one year's period is concerned, it can be:

(a) a continuous process on $[0,t_0]$ ($[0,t_0]$ stands for one Year's period).

(b) a daily average value, which forms a dispersed process from the first to the 365th. .

(c) a dispersed process of the average value of 5 days, 10 days, 15 days, 24 days, of a month process averaged by monthes.

Therefore, according to L. A. Zadeh's expanding principle[7], the dynamic process of suitability degree of temperature factor $\underset{\sim}{S}_T(t)$ is easy to induce from function $T(t)$. ie.

$$T(t) \xrightarrow{s_T} \underset{\sim}{S}_T(t) \tag{6}$$

Using the common signs in the theory of fuzzy collection, we acn describe it as:

Continuous process: $$\underset{\sim}{S}_T(t) = \int_{t\in[0,t_0]} S_T(t)/t \tag{7}$$

or Diaspersed process: $$\underset{\sim}{S}_T(t) = \sum_{i=1}^{k} S_T(t_i)/t_i \tag{8}$$

Where, k is divided interval number during one year. $\underset{\sim}{S}_T(t)$ is the annual dynamic processes of suitability degree of temperature T, which reflects the suitability state of the temperature factor for crops development, so it is called as temperature suitability state.

Similarly, we can induce the suitability state of other ecological factors. If the suitability state of ecological factor $x_i(i=1,2,\cdots,n)$ in $\underset{\sim}{S}_{x_i}(t)$, the dynamic process of agroecological environment can by described as following by fuzzy vector:

$$\underset{\sim}{S}_e(t) = \begin{bmatrix} \underset{\sim}{S}_{x_1}(t) \\ \underset{\sim}{S}_{x_2}(t) \\ \vdots \\ \underset{\sim}{S}_{x_n}(t) \end{bmatrix} \tag{9}$$

The following is a group of models of agroecological environment suitability degree:

(1). Resource model:

$$\underset{\sim}{S}_{e_1}(t) \triangleq \frac{1}{n}\sum_{i=1}^{n}\underset{\sim}{S}_{x_i}(t) \tag{10}$$

continuous process:

$$\underset{\sim}{S}_{e_1}(t) = \int_{t\in[0,t_0]} \frac{1}{n}\sum_{i=1}^{n} S_{x_i}(t)/t \tag{11}$$

or dispersed process:

$$\underset{\sim}{S}_{e_1}(t) = \sum_{i=1}^{k} \frac{1}{n}\sum_{j=1}^{n} S_{x_j}(t_i)/t_i \tag{12}$$

The resource model shows the combination of all ecological factors might provide generalized resource for crop's development.

(2). Efficiency model:

$$\underset{\sim}{S}_{e_2}(t) \triangleq \bigcap_{i=1}^{n}\underset{\sim}{S}_{x_i}(t) \tag{13}$$

continuous process:

$$\underset{\sim}{S}_{e_2}(t)=\int_{t\in[0,t_0]}[S_{x_1}(t)\wedge S_{x_2}(t)\wedge\cdots\wedge S_{x_n}(t)]/t \qquad (14)$$

or dispersed process:

$$\underset{\sim}{S}_{e_2}(t)=\sum_{i=1}^{k}[S_{x_1}(t_i)\wedge S_{x_2}(t_i)\wedge\cdots\wedge S_{x_i}(t_i)]/t_i \qquad (15)$$

The efficiency model shows the matching state of every ecological factors during crops development.

(3)Structural model:

$$\underset{\sim}{S}_{e_3}(t)\triangleq\sum_{i=1}^{n}a_i\underset{\sim}{S}_{x_i}(t) \qquad (16)$$

continuous process:

$$\underset{\sim}{S}_{e_3}(t)=\int_{t\in[0,t_0]}\sum_{i=1}^{n}a_iS_{x_i}(t)/t \qquad (17)$$

or dispersed process:

$$\underset{\sim}{S}_{e_3}(t)=\sum_{i=1}^{k}\Big[\sum_{j=1}^{n}a_jS_{x_j}(t_i)\Big]/t_i \qquad (18)$$

where $a_j(j=1,2,\cdots,n)$ is important value of ecological factor x_j; $\theta<a_j<1,\sum_{j=1}^{n}a_j=1$.

Structural model reflects dynamic process of ecological environmrnt in different agroecological economic structural regions. The choice of $a_j(j=1,2,\cdots,n)$ reflects the important degree of each ecological factor in different type of regional agroecological economic systems. On condition of $a_1=a_2=\cdots=a_n=1/n$, structural model and resource model are same.

(4). Agroecological environmental indices

According to the resource and effiency models, a generalized resource index Er and effifiency index Ee of certain year or many years on average may be developed using on the spot surving (sample) data.

Resource index: $$E_r=\int_0^{t_0}\underset{\sim}{S}_{e_1}(t)\mathrm{d}t=\frac{1}{n}\int_0^{t_0}\sum_{i=1}^{n}\underset{\sim}{S}_{x_i}(t)\mathrm{d}t \qquad (19)$$

or: $$E_r=\frac{1}{n}\sum_{i=1}^{k}\sum_{j=1}^{n}S_{x_j}(t_i) \qquad (20)$$

Er shows potential generalized resources. The bigger E_r is, the greater resource potentiality is, thus the richer resources are.

Efficiency index: $$E_e=\int_0^{t_0}[S_{x_e}(t)\wedge S_{x_2}(t)\wedge\cdots\wedge S_{x_n}(t)]\mathrm{d}t \qquad (21)$$

or: $$E_e=\sum_{i=1}^{k}[S_{x_1}(t_i)\ S_{x_2}(t_i)\wedge\cdots\wedge S_{x_n}(t_i)] \qquad (22)$$

From the point of view of crop's development, efficiency index reflects the matching state of various ecological factors, the bigyer E_e is, the better the match and the cops can grow.

(5). Utilizatien coefficient k

$$k=\frac{E_e}{E_r}\times100\% \qquad (23)$$

Utilizatien coefficient k reflects the degree of use of generalized resources in an area in the process of a crop's development.

3 Applied Example

As an example of the upper models application, the agroecologicsl environment of Gansu's Loess Plateau area has been analyzed by the authors. the Gansu's Loess Plateau area studied by the authors can be divided into three parts by Liu-Pan Mountain and the mountain area of Weihe rivers's source. The first part is the east area to Liu-Pan Mountain, it is called, Longding Loess Plateau, it' s precipitation and heat are rich. The second part is the west area of Liupan Mountain, it is called Longzhong Loess Palteau. It's elevation is 500m higher than Longdong Loess Plateau, but its precipitation and temperature are relativily less. The third part refers to the east area of the mountain area of Weihe rivers's source, it is called Lingxia Loess Plateau. Because it is close to Qingzang Plateau, the condition of water and heat is much different in the area. According to the administrative district of China, the Gansu's loess Plateau area includes Qingyang area, Pingliang area, Dingxi area, Lanzhou city, Baiyin city, the north part of Tianshui area and the east part of Lingxia Hui automus state (see Fig 1.).

3.1 Analysis of agroecological environment suitability

Dry agriculture is the major form of agricultural production in this area. The author has chosen illumination I (hour/day), temperature T(℃), relative humidity R(%), annual precipitation P(mm), ≥ 10℃ accumulated temperature Q(℃), frost-free period D (day), elevation H (m) and soil type L (including moist soil L_1, heilusol L_2 loessal cambisols L_3, sierozem L_4, graycinnamonic soil L_5, brown soil L_6 mountain chestnut soil L_7), etc. as the major agroecological factors of this area. And then draw up the subcollection of this agroecological environment suitability degree by according to the matching relationship of every ecological factors and the developing process of major crops (e. g. winter wheat, spring wheat, maize, millet, potato, ect). On this basis, we have drawn the following conclusion:

3. 1 Ecological factors suitability degree

a. The suitability degree of illuminatin factor I, its subordinate function is:

$$S_I = \mu_{\underset{\sim}{S}_I}(I) = \begin{cases} 0 & I < 5 \text{ houre per day} \\ 1 - \frac{1}{40}(I - 12)^2 & 5 \text{ hours perdag} \leqslant I \leqslant 18 \text{ howrs per day} \\ 0 & I > 18 \text{ hours per day} \end{cases}$$

b. The suitability degree of temperature factor T, its subordinate function is:

$$S_T = \mu_{\underset{\sim}{S}_T}(T) = \begin{cases} 0 & T \leqslant 0℃ \\ \frac{1}{4} + \frac{1}{800}T^2 & 0℃ < T < 20℃ \\ 1 - \frac{1}{400}(T - 30)^2 & 20℃ \leqslant T < 50℃ \\ 0 & T \geqslant 50℃ \end{cases}$$

c. The suitability degree of relative humidity factor R, its subordinate function is:

$$S_R = \mu_{\underset{\sim}{S}_R}(R) = \begin{cases} 0 & 0 \leqslant R < 40\% \\ 1 - \frac{1}{900}(R - 70)^2 & 40\% \leqslant R \leqslant 100\% \end{cases}$$

d. The suitability degree of annual precipitation factor p, its subordinate function is:

$$S_P = \mu_{\underset{\sim}{S}_P}(P) = \begin{cases} 1 & P > 500 \text{ mm} \\ \frac{P - 200}{300} & 200\text{mm} < P \leqslant 500\text{mm} \\ 0 & P \leqslant 200\text{mm} \end{cases}$$

e. The suitablity degree of $\geqslant 10℃$ accumulated temperature factor Q, its subordinate function is:

$$S_Q = \mu_{\underset{\sim}{S}_Q}(Q) = \begin{cases} 1 & Q > 3300℃ \\ \frac{Q - 1500}{1800} & 1500℃ \leqslant Q \leqslant 3300℃ \\ 0 & Q < 1500℃ \end{cases}$$

f. The suitability degree of frost-free period factor D, its subordinate function is:

$$S_D = \mu_{\tilde{S}_D}(D) = \begin{cases} 1 & D > 260 \text{ days} \\ \frac{D - 90}{170} & 90 \text{ days} < D \leqslant 260 \text{ days} \\ 0 & D \leqslant 90 \text{ days} \end{cases}$$

g. The suitability degree of elevation factor H, its subordinate function is:

$$S_H = \mu_{\underset{\sim}{S}_H}(H) = \begin{cases} 1 & H < 1000\text{m} \\ \frac{2500 - H}{1500} & 1000\text{m} \leqslant H < 2500\text{m} \\ 0 & H \geqslant 2500\text{m} \end{cases}$$

h. The soil type factor L, its suitavlity degree subcollection is:

$$\underset{\sim}{S}_L = \frac{0.90}{L_1} + \frac{0.80}{L_2} + \frac{0.70}{L_3} + \frac{0.75}{L_4} + \frac{0.2}{L_5} + \frac{0.3}{L_6} + \frac{0.4}{L_7}$$

Through analyzing the suitability degree of all ecological factors, we can discover the various advantageous and disadvantageous factors of dry agricultural producion for this area. We can then use this information to make the best use of the advantages and bypass the disadvantages for agricultural production on each location.

We find this easily by the simple calculation that the suitability degree of illumination of the area is higher and that the subordinate degree of illumination in most part of the area reaches up to 0. 80. Therefore, the sufficient illumination is an advantageous factor for all agricultural production in the area. But precipitation is a important restrictive factor. The five countries of Yongdeng, Gaolan, Jingai, Jingyuan, Yongjing have a suitability degree of precipitation all below 0. 4. This means that for agriculture to be efficient and we must first build water conservancy projects, open up new water resources and that the road of irrigated agriculture is the correct path for agriculture development. Secondly, low temperature and freezing also are essential restrictive conditions of agricultural production in the area. As far as Dingxi county is concerned, ≥10℃ accumulated temperature is only 2239. 1, and its suitabilty degree is 0. 4, thus forestry and animal husbandry is the major developing direction for effecient land-use in this county.

3. 1. 2 *Agroecological Environment Suitability Degree*

Having analyzing all ecological factors suitability degree, we may draw up the agroecological environment suitability degree subcollection $\underset{\sim}{S}$ of this area. Its subordinate functioin is:

$$S = \mu_{\tilde{S}_t}(I,T,R,P,Q,D,H,L) = 0.05\mu_{\underset{\sim}{S}_I}(T) ++ 0.15\mu_{\underset{\sim}{S}_T} 0.10\mu_{\underset{\sim}{S}_R}(R) + 0.30\mu_{\underset{\sim}{S}_P}(P) + 0.20\mu_{\underset{\sim}{S}_Q}(Q) + 0.10\mu_{\underset{\sim}{S}_D}(D) + 0.05\mu_{\underset{\sim}{S}_H}(H) + 0.05\mu_{\underset{\sim}{S}_L}(L) \quad (10)$$

The analysis of agroecological environment suitabilty degree can help us understand the suitability of agricultural production in a certain environment or region. For example, in certain place of Gansu's Loess plateau area, the average value state of all ecological factors is:

$$(I,T,R,P,Q,D,H,L) = (12,10,60,500,3300,230,1200,12)$$

So the subordinate degree of dry ecological environment suitability degree in this area is:

$$S = \mu_{\underset{\sim}{S}_t}(I,T,R,P,Q,D,H,L) = 0.86$$

which means that the condition of local dry agricultural production is more agvantageous than disadvantageous.

3. 2 *The Evaluation of Agroecological Climatic Condition*

Having studied the relationship between the increase of most crop organisms and all the carious ecological facors, we can draw up the suitability degree of various ecological factors. After that, the research temporal change of suitability degree will determine its most suitable state for agriculture. Therefore, we can use the models introduced as above to calculate the environment index(resource index E_r, efficiency index E_e and utilization ciefficient K) and the potential of environment resources, the degree of matching among all the ecological factors and the environment utilizated efficiency can be described and assessed quantitatively.

If we just consider three factors of temperature T, illumination I and relative humidity R, the agroecological space studied by us becomes the three-dimension space, therefore the agroecological environment described by them becomes the agroecological climatic environment and furthermore the environment resource index, environment efficiency index and environment utilization coefficient become the climatic resource index, climate efficiency index and climatic utilization coefficient. The author selected the temperature, relative humidity and illuminative hour in some major meteorological stations of this area and got the dispersed process averaged by month. Using the above models, the climatic resource index, efficiency index and utilization coefficient of the region represented by these stations is calculated by authors. The comparative conclusion of these and the total illuminative hours, annual precipitation and ≥10℃ accumulated temperature sees to Tab. 1.

Tab. 1 The suitability index of average of many years in Gansu's Loess plateau area

Station Name	E_r	E_e	K	F	P	T_{10}
Zhangjiachuan	5.27	2.65	0.50	2888.0	606.5	2225.2
Qinan	5.67	2.49	0.44	2068.8	507.7	3395.0
Zhang Xian	5.46	3.01	0.55	2925.7	456.0	2443.4
Qinshui	5.61	2.75	0.49	2815.8	574.9	2898.6
Wushan	5.36	2.67	0.50	2730.0	480.6	3084.5
Tianshui Tai	5.81	2.94	0.51	2760.7	556.2	3359.5
Tianshui county	5.80	3.02	0.52	2644.0	508.4	3536.9
Pingliang	5.23	2.60	0.50	2731.3	511.1	2862.8
Jingning	5.34	2.71	0.51	2721.7	479.4	2539.2
Jingchuan	5.81	3.10	0.53	2619.8	549.9	3335.6
Chunxing	5.39	2.78	0.52	2723.0	546.6	3262.0
Zhuanglang	5.34	2.72	0.51	2572.9	547.6	2677.4
Huating	5.56	2.91	0.52	2415.5	606.6	2694.7
Lingtai	5.43	2.91	0.54	2566.6	643.7	2832.6
Jingyuan	4.34	1.20	0.28	2413.1	240.0	3224.4
Hiuning	4.19	1.63	0.39	2324.7	426.7	2088.5
Dingxi	4.19	2.38	0.48	2449.0	429.2	2415.8
Lingtao	5.22	2.73	0.52	2553.9	578.0	2415.8
Tongwei	5.39	2.63	0.49	2483.9	440.3	2371.4
Weiyuan	5.08	2.58	0.51	2450.8	525.6	1938.6
Longxi	5.27	2.70	0.51	2491.7	444.7	2585.4
Yongjing	4.06	0.71	0.17	2552.2	304.2	2871.5
Dongxiang	4.25	1.87	0.44	2392.6	537.6	1584.2
Lingxia city	5.10	2.74	0.54	2528.4	493.9	2328.5
Guanghe	5.21	2.78	0.53	2426.2	502.3	2236.9
Hezheng	5.36	2.78	0.53	2356.4	627.8	1810.9
Kangle	5.20	2.85	0.55	2360.5	562.9	2104.3
Huan county	4.25	1.55	0.37	2033.9	417.7	3058.6
Huachi	4.85	2.31	0.48	2120.3	501.9	2896.7
Qinyang	5.05	2.30	0.46	2190.4	533.8	3209.3
Heshui	4.69	2.25	0.48	2101.1	568.5	2998.0
Zhengyuan	5.03	2.49	0.49	2136.7	504.8	3191.1
Zhengning	4.79	2.47	0.52	2136.5	624.4	2739.2
Ning county	5.23	2.76	0.53	1941.2	572.0	2929.9
Jingtai	3.66	0.25	0.07	1928.7	184.5	2988.7
Yongdeng	3.71	1.02	0.27	2087.6	290.6	2223.9
Gaolan	3.84	0.82	0.21	2163.0	256.1	2798.3
Lanzhou	4.23	1.22	0.29	2133.9	324.7	3234.0
Yuzhong	4.12	1.51	0.37	1840.4	372.2	2370.9

* F-total hours of annual illumination (in hours); P-annual precipitation (mm) $T_{10} \geqslant 10$℃ active accumulated temperature (℃)

We can conclude from the tab. 1 that the climatic resource index, efficiency index and climatic utilization coefficient have the progressive tendency basically from south to north and from east to west in this area, which fully reflexes the attitudinal and longitudinal regional law of agroecological climatic change. For example, the climatic resource index E_r is as high as above 5.80 in the southeast Jingchuan and Tianshui, it is about 5.50 in Zhang Xian, Qingan, Huating and Tintai, etc.. Therefore, we can say that they have greater climatic potential and richer climatic resouces. But Er is only about 3.70 in the northwest part of this Yongjing, lanzhou and Yuzhong, etc. ie, they have smaller climatic resources. As for the matching state of illumination, precipitation and heat, it is getting worse and worse from southwest to northwest, eg. in Zhang Xian, Gangu and Tianshui, etc. the efficiency indexes E_e are all above 3.00, it is 3.10 in Jingchuan while it is only 0.25 in Jingtai of northwest part and it is only 0.82 in Gaolan. Their *Ee* values are below 1.25 in Yongdeng, Lanzhou and Jingyuan.

It is well known that aridity is the underlying restrictive condition of agricultural production in Gansu's Loess plateau area, which is reflexed by the above agricultral climatic suitability indices. For example, the annual precipitation of Jingtai is less than 200mm, its E_r is only 3.36 and E_e is 0.25; The annual precipitation of Gaolan is only 265.1mm, E_r is 3.84 and E_e is 0.82; The annual precipitation of Yongdeng is 290.6mm, E_r is 3.71 and E_e is 1.02. On the contrary, the area which has the bigger climate potential index E_r and efficiency index E_e, has richer precipitation relatively. As for some areas, poor heat and frigity is also one of the essential factors which restrict the agicultural production in the studied area. this can be reflexed from the climatic suitability index too, eg. ≥10℃ accumulated temperature of Dongxing is only 1584.2, where its climatic potential inedx E_r is only 4.25 and efficiency index E_e is 1.87.

Through the above analysis we know that the agroecological climatic suitability indices reflex the suitability of the climatic condition for agricultural production comparatively comprehensively and at the same time the climatic restrictive factors influenced agricultural production are also reflexed by the agroecological climatic suitability indices. Therefore, climatic suitability indices can be regarded as the important basis which we evaluate the condition of agroecological climate comprehensively. The following is the assessment of agroecological climate in Gansu's loess plateau area (see Tab. 2).

Tab. 2 The comprehensive evaluation of agroecological climate in Gansu's Loess Plateau area

Index		Region (represented by the stations)	comment
Er	Ee		
5.20～6.50	2.70～3.40	Zhangxian, Gangu, Tianshui, Tianshui Tai, Jingning, Jingchuan, Chongxing, Zhuanglang, Huating, Lingtai, Longxi, Guanghe, Hezheng, Kangle, Ningxian, Linxia	Greater climatic potential; better matching state of illumination, heat and precipitation; high climatic natural utilizative degree
5.00～6.00	2.00～2.70	Zhangjiachuan, Qinan, Wushan, Pingliang, Tongwei, Weiyuan, Qingyang, Zhengyuan	Greater climatic potential; medium matching state of illumination, heat and precipitaton; medium climatic natural utilizative degree
<5.00	<2.40	Yongjin, Dongxiang, Huangxian, Xian, Huachi, Heshui, Zhengning Jingyuan, Huining, Dingxi, Jingtai, Yongdeng, Lanzhou, Gaolan, Yuzhong	Medium climatic potential while worse matching state of illumination, heat and Precipitation; lower climaticnatural utilizative degree

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农业生态环境适应性近似理论及其应用

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摘　要

本文提出了农业生态环境适应力理论并在现代生态理论的基础上用模糊数学建立了数学模型. 作为此理论应用的一个例子, 本文分析了甘肃黄土高原的农业生态环境. 分析和计算结果对甘肃黄土高原的农业生产布局提供了科学依据. 理论和模型也能用于其它领域.

关键词　近似;农业生态环境理论;应用