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Multi-time Scale Analysis on the Cultivated Land Quantity in China

LIU Zhi-ling[1*], **SUN Yan**[2]

1. The Bureau of Land Resources Nantong, Nantong 226000, China; 2. School of Geographic and Oceanographic Sciences, Nanjing University, Nanjing 210093, China

Abstract This paper briefly introduces the concrete steps of EMD (Empirical Mode Decomposition) method, and then applies EMD method into the multi-time scale analysis on fluctuation of cultivated land quantity and its driving force in China since 1949. This paper also reveals the fluctuation law in the amount of cultivated land quantity. At the same time, based on the fluctuation of different time scales, qualitative forecast on the fluctuation trend of cultivated land quantity in China in future is carried out in order to offer references for establishing prediction model of cultivated land quantity. Research result shows that downward trend of cultivated land quantity is inevitable in China in the future, showing a basic form of an exponential decline during a short period of time. However, situation will be improved with the implementing of a series of land-control policies and paying attention to the issue of rapid reduction of cultivated land. Thus, several suggestions are put forward: ① strengthen the research and control on the cultivated land quality in the overall land use planning; ② enhance the continuity and durability of land macro-control; ③ intensify the protection responsibility of cultivated land for leadership at all levels.

Key words Cultivated land; EMD; Multi-time scale; Driving force; China

1 Background and significance

Cultivated land is an important natural resource for the subsistence and development of the humankind. Maintaining a certain amount of cultivated land is not only an important measure to ensure the food safety, but also the requirement for maintaining China's social and economic sustainable development. China has a large population but little cultivated land. Thus, changes in the number of cultivated land have drawn great attention. Academic argument of " who will feed China" was once very popular around the world[1]. Domestic academic circle started to attach importance to the study on the change of the number of cultivated land in the late 90's. But most of them are qualitative researches based on the land use/cover change or regional comprehensive study affected by environment[2-3]. In recent years, some scholars have started to attach importance to the change tendency of cultivated land and its mathematical relation between driving force factors. And a large number of achievements have been made[3-11]. These researches are singe-resolution based on traditional statistical methods. But changes in cultivated land quantity are affected by many factors with typical non-linear characteristics.

EMD (Empirical Mode Decomposition) method is a method can handle non-stationary and non-linear signal well. Compared with Fourier Spectrum Analysis, Wavelet Analysis and other analysis methods for time series, EMD method can not only handle non-stationary and non-linear signal well, but also is intuitive, direct and adaptive based on experience. Traditional Fourier Spectrum Analysis can obtain a very high resolution within frequency domain. But there is no resolution in the time domain at all. Therefore, traditional Fourier Spectrum Analysis seems powerless to analyze non-linear and non-stationary data, or its result has no a clear physical meaning. Wavelet Analysis has a certain frequency-domain resolution when maintaining the time-domain characteristics of signal. But the uncertainty principle of Wavelet Analysis restricts the improvement of analysis accuracy; and a lot of false harmonics are produced[12-17]. Different from the two methods, EMD method can decompose different scales of the fluctuations or trends in signal, and then produces a series of data sequences with different characteristic scales. And each sequence is called IMF (Intrinsic Mode Function). IMF component includes and highlights the amount of characteristic information in original signal[12-17]. Research result shows that EMD method is one of the relatively good methods to extract dada array trends[17].

Application of EMD method in arable land fluctuation has not yet been reported in China. Thus, we have tried to apply EMD method in the multi-scale analysis on fluctuation and driving force of cultivated land quantity in China since the year 1949, so as to reveal the fluctuation law of cultivated land quantity, and to qualitatively forecast the fluctuation trend of cultivated land quantity in China based on different time scales. On the one hand, we can offer modeling basis for the prediction model of cultivated land quantity in China, as well as certain basis for safety early warning analysis of cultivated land. On the other hand, recommendations can be put forward for policy-making.

2 Introduction of EMD method

EMD method decomposes time signal $X(t)$ into a series of intrinsic mode functions, with the following characteristics in IMF component[12-14,17]: ① according to the global characteristics, the number of extrema is equal to, or at most one number

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* Corresponding author. E-mail: liu0999@sohu.com

different from, the number of zero; ② mean value of two envelope curves connecting both local minimum and local maximum is zero at any point.

EMD is actually a circulated iterative algorithm, and can be described by pseudocode:

(1) Initialize $r_0(t) = X(t)$, where $r_0(t)$ is time series to be analyzed.

(2) Extract IMF component by cyclic operation. ① Let $h_0(t) = r_i(t)$, $j = 1$, where i is the extracting operation of the i^{th} IMF component, j is the operation in extracting the j^{th} cycle of the ith IMF component, $r_i(t)$ is the new time series after eliminating $1, 2, \cdots, i-1$ number of *IMF* component from original time series. ② Calculate the maximum value and minimum value of $h_{j-1}(t)$. ③ Discrete extreme point in step ② is introduced into the whole time segment by cubic spline function, so as to obtain maximum and minimum envelope and to calculate the arithmetic mean $m_{j-1}(t)$ of envelope. ④ Calculate $h_j(t) = h_{j-1}(t) - m_{j-1}(t)$. ⑤ If the sum of $m_{j-1}(t)$ inclines to zero and satisfies the IMF condition ②, we have $IMF_i(t) = h_j(t)$, indicating that the ith IMF is successfully extracted. Thus, this circulation is terminated and enters step ③; otherwise, let $j = j + 1$, return to *b* for circulation.

(3) Let $r_i(t) = r_{i-1}(t) - IMF_i(t)$.

(4) If $r_i(t)$ still has at least 2 extreme points, let $i = i + 1$, return to step (2) for circulation. Otherwise, after all the *IMF* components are extracted, decomposition process comes to an end. And the obtained residual $r_i(t)$ is trend component.

After the iterative algorithm of EMD, time series can realize decomposition:

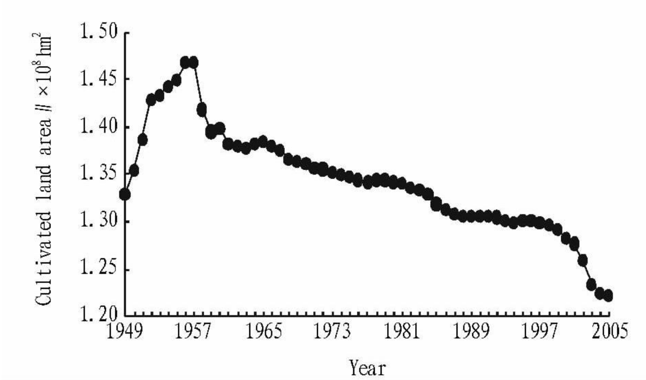
$$X(t) = \sum_{i=1}^{n} imf_i(t) + r_n(t).$$

IMF components obtained from the process of EMD are decomposition process of different scales. High frequency signal is isolated from the low frequency signal; and trend component $r_n(t)$ is finally obtained.

3 Multi-time scale analysis on the cultivated land quantity in China

3.1 Basic tendency of cultivated land quantity in China Fig. 1 illustrates the change of cultivated land quantity in China since the year 1949, indicating that cultivated land quantity changes annually. Area of cultivated land has increased year by year from 1949 to 1957. And then cultivated land shows a downward trend after 1958. During the year 2000 and 2003, the area has dropped sharply, and then declined at a slower rate in the years 2004 – 2005, the same as the rate in 1958 – 1999.

3.2 Multi-time scale analysis Fig. 2 reports the EMD of cultivated land quantity in China since the year 1949. Five IMF components and one trend component *R* are obtained through EMD decomposition. Table 1 shows the IMF components and the variance contribution of trend component *R*. Contribution rate of trend component *R* is the largest (35.40%), indicating a significant trend of cultivated land quantity in China since the year 1949. Contribution rates of IMF4 and IMF5 are 31.52% and 26.90%, taking the second and third places, respectively.



Note: The data of 1949 – 1996 and 1996 – 2003 are from the http://www. sannong. gov. cn, and the http://www. agri. gov. cn, respectively. Data of 2004 – 2005 come from the *Statistical Bulletin of National Economy and Social Development* (http://www. sannong. gov. cn). Besides, due to the inconsistency of statistical caliber, data after the year 1996 increase sharply. In order to achieve a unified standard, data are processed according to reference [8]. So the data in this research have all been processed.

Fig. 1 Basic tendency of the cultivated land quantity in China since 1949

This indicates that fluctuation scales of cultivated land quantity in China are mainly the IMF4 and IMF5. According to the fluctuation pattern of IMF4 (Fig. 2d), cultivated land quantity in China has experienced about one and a half periodic fluctuation, showing a quasi-34-year fluctuation. However, according to the fluctuation pattern of IMF5 (Fig. 2e), cultivated land quantity in China has experienced a periodic fluctuation, indicating a quasi-57-year fluctuation.

Table 1 Variance contribution of IMF components and their orders

	Variance contribution//%
R	35.40
IMF4	31.52
IMF5	26.90
IMF3	3.39
IMF2	2.41
IMF1	0.38

Existing research points out that cultivated land quantity shows a fluctuating change in China since 1949. But before the year 1979, it increases on the whole. After the 1980s, cultivated land quantity shows a slow decline. After the year 1999, cultivated land quantity decreases sharply due to ecological restoration. Problems caused by this, such as food security and cultivated land security, deserve our full attention. After a period of rapid and large-scale ecological restoration, the speed of ecological restoration in China will gradually slow down. And food security and cultivated land security will become the major issues affecting the change of arable land quantity in China. Thus, strict protection policy for cultivated land is bound to be implemented. It is expected that after the year 2010, cultivated land quantity in China will become stable[11], which has the

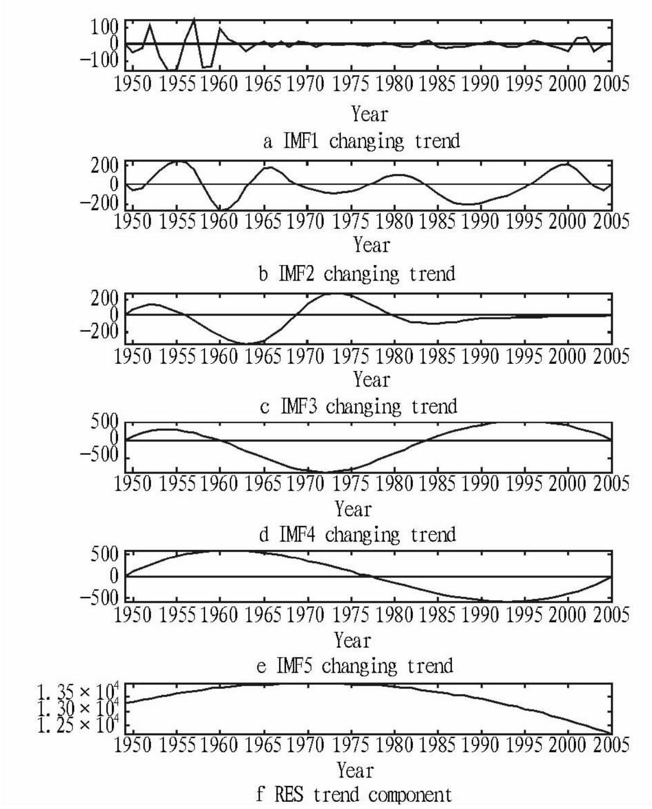


Fig. 2 EMD decomposition of cultivated land quantity in China since 1949

same result as EMD method. According to the trend curve of 2f, arable land quantity maintains a steady increase in China from 1949 to 1978; after the year 1978, arable land quantity shows a rapid downward trend. What's more, these two stages basically change with an exponential form according to the shape of curve. Therefore, it can be concluded that arable land quantity in China will continue to decline in the future with an exponential form within a short period of time. According to the pattern of 34-year periodic fluctuation (IMF4), cultivated land quantity will keep an downward trend in China in the next 5 – 10 years. However, according to a larger time scale (IMF5), cultivated land quantity will gradually go through the trough phase in the next 5 – 10 years. The situation will be improved with the implementation of a series of land-control policies and the government's paying attention to the issue of rapid reduction of cultivated land.

4 Analysis of driving force

Analysis of driving force will help to grasp and analyze the direction of future changes in cultivated land. Driving force for the change of cultivated land mainly includes three aspects, which are natural factor, social factor and economic factor. Among them, natural factor is mainly the damage caused by natural disasters. China is a country having serious flooding, desertification and other natural disasters. Cultivated land area damaged by disasters reaches about 45 thousand hectares on average each year[10]. With the improvement of disaster prevention capacity in China, part of the cultivated land damaged can be reconstructed and reused in future. Therefore, it is believed that land area damaged by natural disasters will gradually be reduced[18]. Impact of natural factors on cultivated land will become smaller; and the influences of economic and social factors will become larger. It is concluded that driving forces of policy, economy and population are the main socio-economic factors affecting the quantity change of cultivated land[4]. And the fluctuation of cultivated land area is mainly caused by the factors of policy. However, under the market economy of macro-control, policy-making is mainly based on socio-economic development situation. Thus, EMD analysis on population and economy can be conducted based on relevant data through extracting their change characteristics, so as to grasp the change trend of cultivated land in China.

Fig. 3 and 4 carry out EMD decomposition of the population and GDP in China since the year 1949, respectively. As a result, population obtains one IMF component and one trend component; while GDP has two IMF components and one trend component. Table 2 reports the variance contribution of each IMF component and trend component *R*. According to the variance contribution of population, contribution rate of trend component *R* reaches 99.90%, which is extremely big, indicating that population trend is very significant in China after 1949. Based on the curve of trend component (Fig. 3b), China's population trend shows a rising trend since the year 1949 and will continue to rise in the future. According to the IMF components (Fig. 3a), population fluctuates greatly in China before the 70s, and then gradually shows a smaller fluctuation after the 70s. In recent years, amplitude of fluctuation is relatively small. According to the variance contribution from GDP decomposition, contribution rate of trend component *R* reaches as high as 85.21%, followed by IMF2; and contribution rate of IMF1 (only 0.20%) is the smallest. This indicates that China's GDP has a more obvious trend since 1949. Fig. 4c shows a basically "U" type with a downward trend before the 70s and a steady exponential increase after the 70s. According to the shape of IMF2 component (Fig. 4b), China's GDP has experienced a periodic fluctuation since 1949. China's economy will go through the trough phase with 54-year scale in the future, and move towards the next peak.

According to the EMD decomposition results of population and EMD, the two have very significant trend. Judging from the trend curve, they will continue to rise in future, which is consistent with the result of previous research[10]. Because population and GDP have a negative impact on the change of cultivated land, each round of the substantial growth of GDP is accompanied by a new round of landslide of cultivated land. Peak period of GDP exactly corresponds to the trough period of cultivated land. At present, China's national economy is at a period of rapid development with the improvement of urbanization level. Along with this, a large number of rural surplus labor forces come into cities and turn into urban population. Therefore, establishment of a large number of new cities is promoted. Meanwhile, with the development of socio-economy, existing cities and towns need to adjust their industrial structure, and to carry out modernization construction and renovation of the old city, which will occupy part of cultivated land[10]. Therefore, it is inevitable that the amount of cultivated land quantity in China will continue to decline in future.

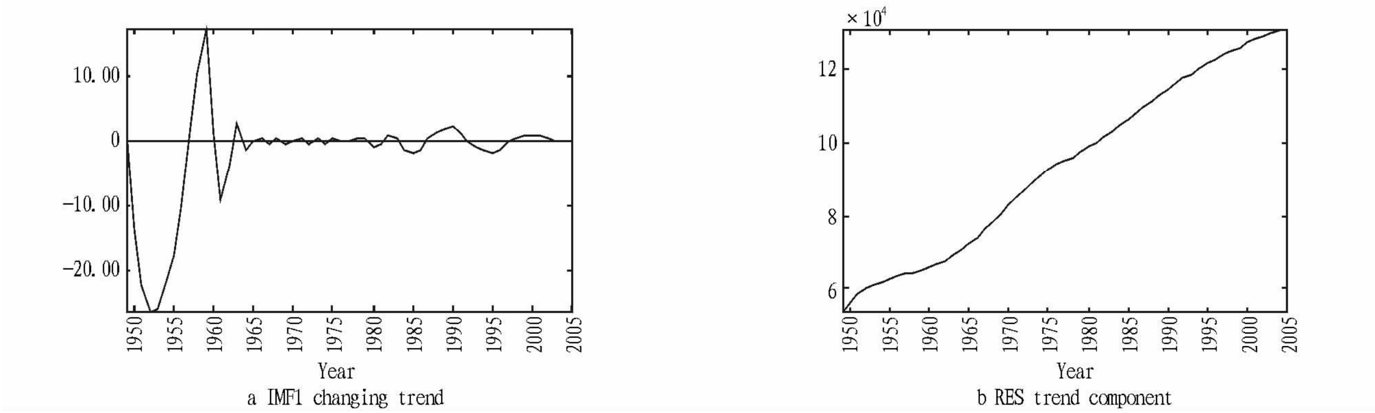


Fig.3 EMD decomposition of population and GDP in China since 1949

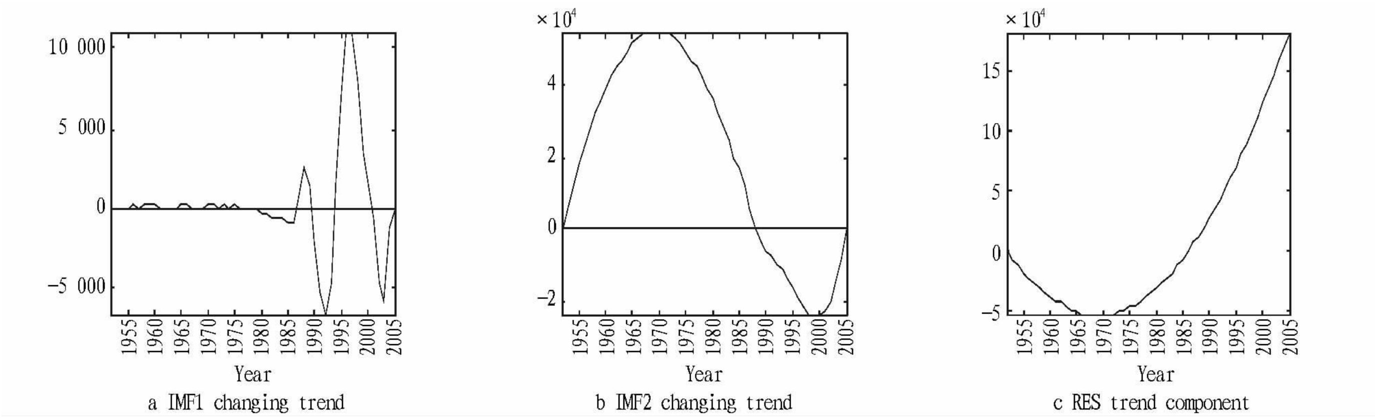


Fig.4 EMD decomposition of GDP in China since 1949

5 Conclusion and suggestion

Based on the EMD decomposition of cultivated land quantity and two driving factors since 1949, the following conclusion can be obtained: ① cultivated land quantity in China will inevitably decline in future; and it will be in a basic form of exponential decline during a short period of time according to the trend curve analysis of EMD decomposition for cultivated land quantity in China; ② according to the 34-year periodic fluctuation, cultivated land quantity in China shows a downward trend in the next 5 – 10 years. However, according to a larger time scale, cultivated land quantity will gradually go through the trough phase within 5 – 10 years. The situation will be improved with the implementation of a series of land-control policies and the government's paying attention to the issue of rapid reduction of cultivated land.

Table 2 Variance contribution of the IMF components of population and GDP %

Item	Population component	GDP component
IMF1	0.10	0.20
IMF2	–	14.59
R	99.90	85.21

Based on the above analysis, we put forward several suggestions. ① Strengthen the research and control on cultivated land quantity during the overall planning of land use. According to the current situation of rapid economic and population growth, it is very difficult to maintain the 120 million hectares arable land. We can further approve the bottom line of cultivated land from the aspects of improving grain unit yield and precision agriculture and adjusting people's diet structure, so as to coordinate the relationship between the cultivated land and the economic construction and social development[19]. ② Strengthen the sustainability and durability of land macro-control. Since the year 2003, land quantity has become a tool to implement national macro-control and the Ministry of Land and Resources has become an important department for macro-control. A series of land policies have been put forward and have been adjusted combined with other policies. Remarkable results are achieved on slowing down the rapid decline of arable land area and keeping down occupation of land. We should perfect the existing structure and function of regulation system in future, and fully exert the function of land policy on macro-control. ③ Strengthen the responsibility of administrative leadership for cultivated land protection.

Moreover, applying EMD method in the analysis on cultivated land change and its driving factors can help to further grasp the characteristics and rules of cultivated land change, offering new theoretical tools for an in-depth exploration on the complexity and quantitative forecast of cultivated land change. EMD method has significant advantages in treating with non-linear and non-stationary series, compared with traditional statistical methods and power spectrum analysis. However, there are still some problems in EMD method. For instance, during the process of EMD decomposition, interpolation operation of signal is needed. But due to the shortage of data quantity at signal edge, edge effect becomes inevitable[20]. Therefore, how to improve these shortcomings will be an important task for future research.

References

[1] BARKIN D, BART RI, DE WALT BR. Food crops vs feed crops: global substitution of grains in production[J]. Boulder & London: Lynne Rienner Publications, 1990.

[2] TURNER IIBL, SKOLE D, SANDERSON S, *et al*. Land-use and land-cover change: science/research plan[R]. IGBP Report No.35 and HDP Report No.7. Stockholm: IGBP, 1995.

[3] ZHOU BZ, ZHAO QG, YANG H. Study on the change of cultivated land and its regulation countermeasure in Jiangsu Province[J]. Acta Pedologica Sinica, 2003, 40(5):665 –671. (in Chinese).

[4] YANG GS. The process and driving forces of change in arable land area in the Yangtze River Delta during the past 50 years[J]. Journal of Natural Resources, 2001, 16(2):121 –127. (in Chinese).

[5] LI XB. Change of arable land area in China during the past 20 years and its policy implications[J]. Journal of Natural Resources, 1999, 14(4):329 –333. (in Chinese).

[6] BAI WQ, ZHAO SD. An analysis on driving force system of land use changes[J]. Resources Science, 2001, 23(3):39 –41. (in Chinese).

[7] ZHANG M. Statistical analysis to regional land use structure and its driving forces[J]. Journal of Natural Resources, 1999, 14(4):381 –384. (in Chinese).

[8] WANG M, QU FT. Driving forces of arable land changes in China in the past 50 years based on variance rate analysis[J]. Resources Science, 2005, 27(2):39 –44. (in Chinese).

[9] LI JG, HE CY, SHI PJ, *et al*. Change process of cultivated land and its driving forces in Northern China during 1983 –2001[J]. Acta Geographica Sinica, 2004, 59(2):274 –282. (in Chinese).

[10] SUN Y, LIN ZS, LIU HY. Changing characters of cultivated land area and its driving forces in China[J]. Resources Science, 2005 (2):57 –61. (in Chinese).

[11] FENG ZM, LIU BQ, YANG YZ. A study of the changing trend of Chinese cultivated land amount and data reconstructing: 1949 –2003[J]. Journal of Natural Resources, 2005, 20(1):35 –43. (in Chinese).

[12] HUANG NE, SHEN Z, LONG SR, *et al*. The empirical mode decomposition and the Hilbert spectrum for nonlinear and non-stationary series analysis[J]. Proc R Soc Lond A, 1998, 454:899 –995.

[13] HUANG NE, SHEN Z, LONG SR. A new view of nonlinear water waves: the Hilbert spectrum[J]. Annual Review of Fluid Mechanics, 1999, 31:417 –457.

[14] LIN ZS, WANG SG. EMD analysis of Northern Hemisphere temperature variability during last 4 centuries[J]. Journal of Tropical Meteorology, 2004, 20(2):90 –96. (in Chinese).

[15] DENG YJ, WANG W, QIAN CC, *et al*. Empirical mode decomposition method and boundary process in Hilbert transform[J]. Chinese Science Bulletin, 2001, 46(3):257 –263. (in Chinese).

[16] XIONG XJ, GUO BH, HU YM, *et al*. Application and discussion of empirical mode decomposition method and Hilbert spectral analysis method[J]. Journal of Oceanography of Huanghai & Bohai Seas, 2002, 20(2): 12 –21. (in Chinese).

[17] LIU HY, LIN ZS, ZHANG MY. Analysis on the fluctuation of grain output in China and its causes at multi-time scale based on empirical mode decomposition method[J]. Journal of Natural Resources, 2005, 20(5):745 –751. (in Chinese).

[18] JIA SF, ZHANG HX, MENG XJ. Forecast and countermeasures of the change of the cultivated area of China[J]. Progress in Geography, 1997, 16(1):25 –31. (in Chinese).

[19] SUN X, LIN ZS, SUN Y. Dynamic prediction and suggestion of total farmland in China[J]. Journal of Natural Resources, 2005, 20 (2):200 –205. (in Chinese).

[20] MENG Z, DAI GP, LIU B. Characteristics study on time-frequency analysis method based on empirical mode decomposition[J]. Chinese Journal of Sensors and Actuators, 2006, 19(4):1029 –1032. (in Chinese).

[21] ZHANG W, FAN H, ZHAO HD, *et al*. Prediction and index decomposition of suitable arable land quantity in Guangyuan City[J]. Journal of Anhui Agricultural Sciences, 2008, 36(34): 15105 –15107. (in Chinese).

[22] SUN Y, LIN ZS, JIN XB, *et al*. Dynamic model and measures of total area of farmland in China[J]. Scientia Geographica Sinica, 2008, 28(3):337 –342. (in Chinese).

[23] LI FQ, LI JF, MENG PW. The study of the predictive method about the quantity of cultivated land reserved in general land use plan [J]. Journal of Anhui Agricultural Sciences, 2007, 35 (1):168 –169. (in Chinese).

中国耕地保有量多时间尺度分析

刘志凌[1],孙 燕[2] (1.南通市国土资源局,江苏南通 226006;2.南京大学地理与海洋科学学院,江苏南京 210093)

摘要 经验模型分解(EMD)方法一种可以很好地处理非平稳、非线性信号的方法,也是目前提取数据序列趋势的较好方法之一。简述了 EMD 方法的具体步骤,并将 EMD 方法应用于 1949 年以来中国耕地保有量波动及其驱动力的多时间尺度分析,揭示了耕地保有量的波动规律,同时根据分解出来的不同时间尺度的波动对中国未来耕地保有量波动趋势进行定性预测,一方面为建立耕地保有量预测模型提供了建模依据,为耕地安全预警提供一定的分析,另一方面可为土地政策的制定提出建议。研究结果表明,中国耕地保有量在未来一段时间内继续下降的趋势将不可避免,且短时间内可认为基本呈指数形式下降。从 34 年周期的波动形态来看,未来 5 ~ 10 年耕地保有量将继续下降,但从更大的时间尺度 57 年周期的波动形态来看,未来 5 ~ 10 年耕地保有量将逐步度过波谷阶段,随着国家对耕地快速减少问题的重视和一系列土地调控政策的颁布与实施,形势将有所好转。因此提出几点建议:①加强土地利用总体规划中耕地保有量的研究和控制;②加强土地宏观调控的持续性和持久性;③强化各级行政领导耕地保护职责。

关键词 耕地保有量;EMD;多时间尺度;驱动力