ENVIRONMENTAL AND EARTH SCIENCES RESEARCH JOURNAL
Vol.2, No.3, 2015, pp.1-8
http://dx.doi.org/10.18280/eesrj.020301

ANALYSIS ON TEMPORAL AND SPATIAL VARIATION OF FPAR IN HUNAN PROVINCE

YU Guang-hui, TIAN Qian-jin, YANG Yue-long and MO Hong-wei

The School of Architecture & Urban Planning, Hunan University of Science and Technology, Xiangtan Hunan 411201, China.

Email: yuguanghui107@aliyun.com

ABSTRACT

Based on the MODIS15A2 images, Using RS and GIS obtain date in 14 cities of Hunan province to analyze temporal and spatial variation of FPAR in Hunan province during 2001-2008 years. The result showed that time variation law of Hunan province FPAR when from analysis on the month of July and September for higher in FPAR distribution, there was wave trough obvious in August and we also found that FPAR distributed more higher in summer and autumn than spring and winter. The value of the distribution of summer in the highest, at least in winter. Through the analysis of the laws for years, we discovered FPAR distributed the highest in 2004 during 8 years, but 2002 were the lowest, and FPAR distribution were volatile. Analyzed the 14 cities' FPAR distribution, the order of the FPAR from more to less as the follow: Yueyang city>Changsha city>Yiyang city>Xiangtan city>Zhuzhou city>Changde city>Zhang Jiajie city>Huaihua city>Chenzhou city>Loudi city>Shaoyang city>Hengyang city>Yongzhou city>Xiangxi Autonomous Prefecture.And the order of FPAR growth rate as the follows: Yiyang city> Hengyang city> Yueyang city> Xiangtan city>Zhang Jiajie city> Zhuhou city>Changsha city> Loudi city> Huaihua city> Xiangxi Autonomous Prefecture>Changde city> Chenzhou city> Shaoyang city> Yongzhou city.

Keywords: Hunan province, FPAR, Temporal-spatial.

1. INTRODUCTION

FPAR means the proportion that PAR partly absorbed by green vegetation makes in the total PAR that has absorbed by the canopy [1]. It shows the energy absorptive capacity of plant canopies and serves as the criteria that how much sunlight can be absorbed in the effective optical radiation wavelengths by green vegetation. FPAR is a basic physiological parameter which demonstrates the energy exchange process of vegetation structure and relative energy [2]. The principle of photosynthesis which is the major physiological process of vegetation is to promote a series of complicated biochemical reaction and eventually turn inorganic substance into organic ones. Therefore, FPAR is considered as an important parameter for establishing the model of carbon circle and evaluating the output of crops. In addition, FPAR serves as a basic characteristic parameter for the model of water cycle, atmosphere model, biological model, geographic model, chemical model, and ecological model. In the study of global changes, FPAR is the basic variables to describe terrestrial ecosystem, so it's meaningful to obtain FPAR accurately and rapidly [2, 4, 6-7].

Dong Zhenguo and Yu Huning have already studied PAR and its relative theory. They found daily FPAR is correlated to SVI by measuring instantaneous spectrum and PAR. Tucker, Curran, Jackson and Sellers have studied SVI, APAR, and vegetation characteristics such as LAI or the vegetation coverage degree respectively in 1979, 1983 and 1985 [3]. A lot of researches have been done to PAR in foreign countries during 1980s and 1990s and these researches focused on the inversion of FPAR statistic and physical model by using remote sensing data and then calculated NPP so as to study carbon balance. Nevertheless, the study in this field in China was relatively later than foreign countries and it was not until in 1980 researchers like Liu Hongshun [5] first studied PAR followed by researchers like Guo Zhihua [8] who estimated FPAR and analyzed its temporal and spatial variation in Guangdong Province by taking use of RS and GIS software. Zhou Xiaodong[9]observed PAR of corn canopy in summer and studied the relation between FPAR and LAI. Researchers such as Wu Bingfang[10] studied FPAR and LAI by using remote sensing technology. Gao Yanhua [11] came up with the conception of FPAR by remote sensing simulation to effective FPAR absorbed by chlorophyll. Yang Fei [12] measured FPAR of corn and soybean canopy and studied their daily variation law and factors influencing the variation. Li Gang [2] analyzed the temporal variation law of FPAR of leymus chinensis meadow steppe. Li Jin [13] analyzed the variation law of FPAR of leymus chinensis meadow steppe in Hulun Buir Grassland in 2010 and verified the model of Hulun Buir

Grassland's FPAR/LAI in 2011. Dong Taifeng [14] summarized the research based on the estimation method of remote sensing light and effective absorption ratio, and provided certain reference value for improving the accuracy of FPAR data. Ba Jialiang [15] estimated FPAR/LAI of hyperspectral data crops. Researchers like Zhang Jian [1] carried out remote sensing inversion study to FPAR based on the principle of energy balance. He Jia [16] did research to hyperspectral remote sensing monitoring model of winter wheat's FPAR and this FPAR was collected in different growing conditions of winter wheat. At present, studies on active radiation in Hunan Province are rarely reported and there is almost no relevant research on temporal and spatial variation of FPAR. Choosing Hunan province as the study site, the author analyzed the dynamic variation features of FPAR in terms of time and space. By processing FPAR data of Hunan Province collected for eight years, the author gave a tentative study on the characteristics of monthly, seasonal and yearly variation of FPAR as well as the factors influencing the variation. The author analyzed the dynamic distribution of FPAR in 14 cities of Hunan Province from the spatial aspect and found out the relevant reason according to local actual conditions so as to provide data support to the estimation of grain output and lay theory foundation for sustainable development

2. THE OVERVIEW OF STUDY SITE

Located in east longitude 108°47′—114°15′ and northern latitude 24°38′—30°08′, Hunan Province consists of 13 cities, 1 autonomous prefecture and 122 counties. It lies in the transitional zone between Nanling Mountains of the Yunnan-Guizhou Plateau and Jianghan plain of Chiang-nan Hilly Region. Surrounded by mountains in East, South and West, Hunan Province inclines to north central part whose terrain is low and flat and presents a "Horseshoe" on its surface. Wuling Mountains lies in the northwest part, Xuefeng Mountains stands in the west, and Nanling Mountains stands in the south. The geomorphic type of Hunan Province is complicated and various, but the major ones are mountains and hills. Mountains make up the biggest proportion of the total area about 51.2%, followed by Hills and dowland about 29.3%, plain about 13.1% and water about 13.1%. The climate type of Hunan Province is subtropical monsoon climate which is characterized by warmth, humidity, enough sunlight, four distinctive seasons and rain and heat at the same period. China belongs to Holarctic region according to the plant partition. Subtropical humid forest in southern part of China is one of the main forests in southern China. Up to 2013, the annually forest coverage ratio of Hunan Province has climbed to 57.52%.

3. DATA RESOURCE AND PROCESSING

The data that has been introduced in the paper included administrative map of Hunan Province and MOD15A2 provided for free by NASA covered Hunan, Guangxi, Guangdong, Fujian and Jiangxi Province. Product MOD15A2 includes LAI and FPAR. Spatial resolution is 1KM and temporal resolution is one day and eight days. At present, the most advanced LAI/FPAR product provided by NASA is the one with 1KM spatial resolution and eight-day temporal resolution.

ERDAS9.2 and ARCGIS9.3 are used as the data processing platform and Excel is used to process and analyze data. With the help of software ERDAS9.2, MOD15A2 data form HDF can be turned into TIFF and the projection type Sinusoidal can be turned into ALBERS. Then, MOD15A2 products can be put together. In the Spatial Analyst section of ARCGIS9.3, the monthly, seasonal and yearly average value of FPAR can be worked out. And the average value of FPAR in each city of Hunan Province can be corresponding calculated by using the ARCGIS9.3 spatial analyzing section.

4. ANALYSIS ON THE TIME VARIATION OF FPAR

4.1 Analysis on Monthly Changing Characteristics of FPAR in Hunan

From figure 1: Hunan FPAR high value occurred in July and September, and the highest value was about 24%; the lowest value appeared in February, was about 10%. The gap between the highest and lowest value was 14%. The total changing trend of FPAR was on the rise from January to September, appeared a decrease from December to September, and had slightly decline in February where was a relatively small trough due to the average temperature is minimum, limiting the rate of normal life activities of the vegetation; and in August due to food crops harvested, so a relatively great trough appeared. The growth range of FPAR is large and its speed is fast from February to April, mainly due to vegetation recovery reviving that made leaf area larger, increased light interception area and enhanced the ability of absorbing solar radiation. Vegetation grow quickly in April, May and June , leaf area increased to a certain extent, and due to the increase of the solar height angle, FPAR is increasing, but the growth is relatively slow, and the change is not big. While from September to December, due to the partial vegetation began shedding their leaves, grass is withered, grain crops harvested and the reduction of the average solar radiation, FPAR declined with a rapid rate, and decreased by 13% in December.

4.2 Analysis on Seasonal Changing Characteristics of FPAR in Hunan

From figure 2: FPAR high values are mainly concentrated in summer and autumn, and low values are in spring and winter. The total seasonal trend of FPAR distribution is increased from spring to summer, and the maximum value is about 23% in summer; and declined from summer to winter, the minimum value is about 12% in winter. Due to the rapid growth of vegetation in spring to summer and the increase of average solar radiation, FPAR growth rate is fast. Although it shows a downward trend from summer to autumn, the change is not big, but the speed of decline accelerated from autumn to winter, and the fluctuation is relatively large.

FPAR seasonal distribution: the highest value is in summer, followed by autumn, spring and winter. Because of the fast growing period of green vegetation and grain crops in summer, good vegetation coverage, the total amount of the total solar radiation (PAR) is high, and the absorption capacity of the vegetation to the solar radiation is high, and the FPAR value is the highest. And in autumn deciduous vegetation fell leaves, grass withered, grain crop is ripe for harvest, leaving evergreen vegetation (including evergreen coniferous forest, broad-leaved evergreen forest and bamboo) and deciduous shrub forest, vegetation coverage reduced, the solar radiation absorption capacity is weak, FPAR values less; but FPAR values in autumn are higher than that of in spring, mainly because the spring weather is changeable, more rain, while autumn weather is dry and sunny; due to the crops and grassland returning green in spring, deciduous vegetation recovery, while deciduous vegetation fell leaves, grass withered and less solar radiation , so FPAR value in spring was higher than that of in winter.

4.3 Analysis on Annual Changing Characteristics of FPAR in Hunan

Analysis on 8 years (from 2001 to 2008) changing characteristics of FPAR in Hunan (Fig.3). The fluctuation of FPAR is large during those 8 years, appearing the characteristics of "two peaks and two valleys". The fluctuation of FPAR value from 2001 to 2005 was larger than that of from 2005 to 2008. FPAR values decreased rapidly in 2002, and fell to lowest, was about 16.5%, and the first wave trough appeared; from 2002 to 2004 FPAR grew rapidly, in 2004 reached the highest value, about 19%, the first peak appeared. And in 2005 there was greatly decrease, the second trough appeared; during 2005 to 2008 FPAR was showing the first slow growth trend, in 2007 reached its peak, and the second peak appeared, but in 2008 showed a downward trend. The fluctuation of FPAR average annual value in Hunan is mainly related to the coverage of vegetation and the meteorological disasters. Policy factors (including the policy of returning farmland to forests and afforestation) play a role in promoting. Hunan in 2000 started the implementation of returning farmland to forest pilot and in 2002 large-scale implementation of the project of conversion of cropland to forest, due to ecological disaster affected area and disaster area are arrived 2806000 hm2 and 1859000 hm2 respectively, and the coverage of the disaster was serious. So the year of 2002 was marked the lowest FPAR value during the 8 years average distribution; due to carry out large-scale conversion of cropland to forest and afforestation engineering, in 2004, Hunan forest coverage rate increased by 0.65 percentage points [18], and the disaster area and the damage area compared with the year of 2005 - 2008 is less, so the average value of FPAR was highest in 2004. In 2005, Hunan was subjected to large freezing weather, causing serious damage to agriculture and forestry, including crops affected area of 20.7 million Hm2, inundated area of 14 million Hm2, economic loss of 20 billion RMB, so FPAR values declined sharply in this year; vegetation revitalized from 2006 to 2007 and FPAR values increased year by year. In 2008, Hunan was suffered to rare large disasters of frozen, the freezing disaster compared that of in 2005 was lasted longer, influenced wider, frozen intensity, disaster heavier, and the direct economic losses reached 680 million RMB [20-21], so the FPAR value showed a rapid decline in 2008.

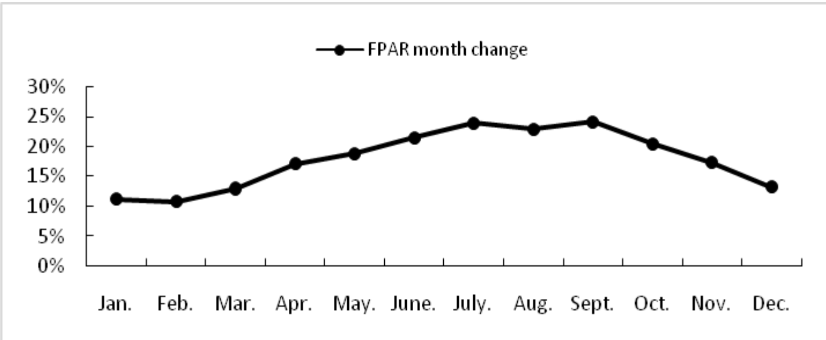

Figure 1. The average monthly FPAR change curve of 2001-2008 in Hunan

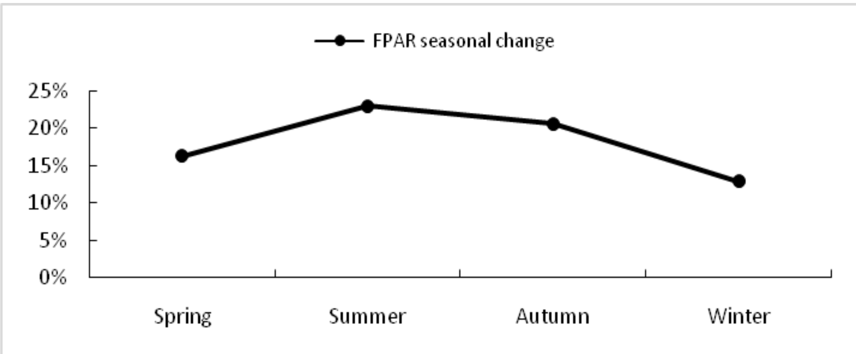

Figure 2. The average seasonal FPAR change curve of 2001-2008 in Hunan

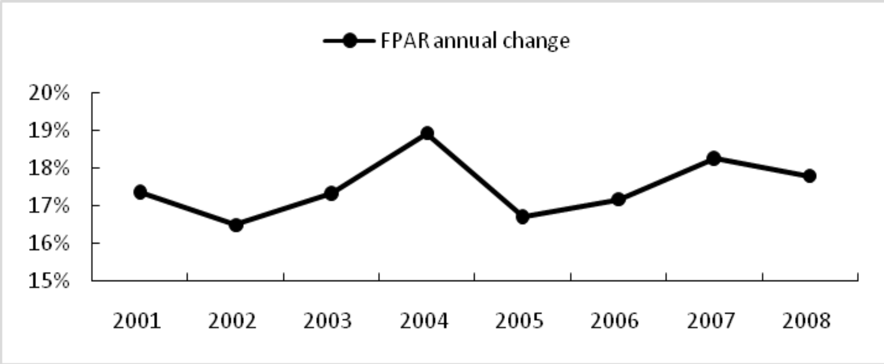

Figure 3. The average annual FPAR change curve of 2001-2008 in Hunan

5. ANALYSIS ON THE SPATIAL VARIATION OF FPAR

5.1 Differences on Spatial Distribution of FPAR in Hunan

The FPAR value of Hunan is basically showing the spatial distribution pattern of high in east and north, low in west and south. From figure 4: high average FPAR values are concentrated mainly in the Yueyang city was the highest, while FPAR values of Changsha city, Zhuzhou city and Xiangtan city these three cities are relatively close, and the difference is relatively small. FPAR values are relatively lower in Western Hunan, southern Hunan and central Hunan these three areas. FPAR value distribution is not uniform in Western Hunan, and the difference is the greatest. The values in Xiangxi Autonomous Prefecture, Huaihua city and Zhangjiajie city are different. Among Yiyang city, Loudi city and Shaoyang city these three cities, the values of Loudi Yueyang city and Shaoyang city are close, and the value of north and east of Hunan, among those, FPAR value of Yiyang city is relatively high. The distributions of FPAR value in Hengyang city, Yongzhou city, Chenzhou city are more uniform,and the difference is small. The value of Chenzhou city is higher than that of in Yongzhou city, while Hengyang city is close to Yongzhou city

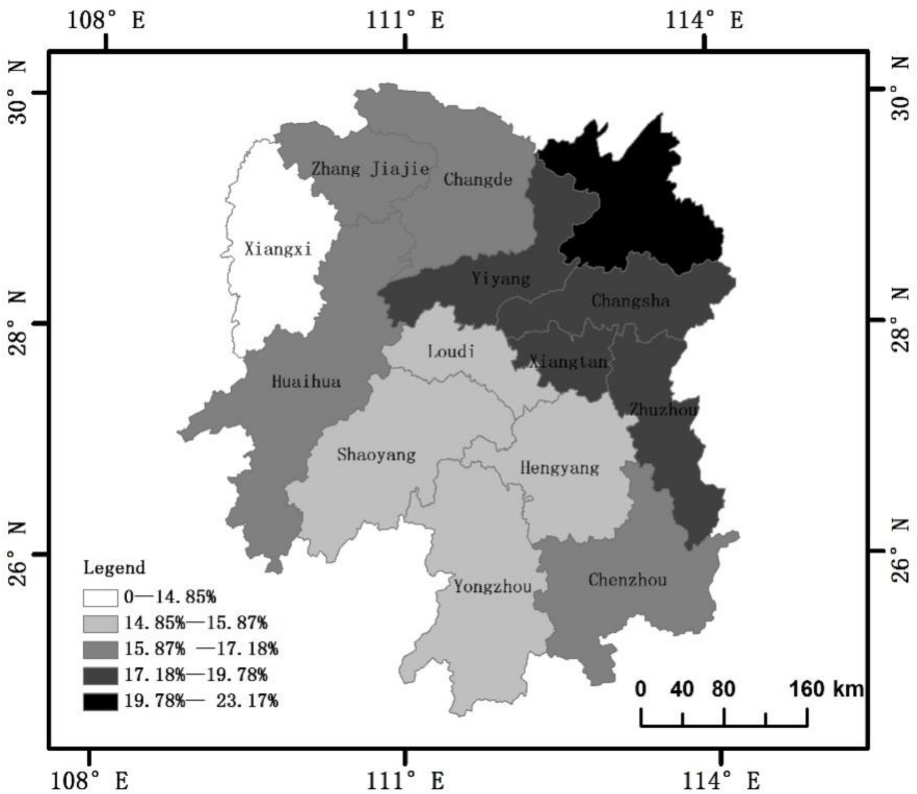

Figure 4. The average annual spatial variation of FPAR from 2001 to 2008 in Hunan

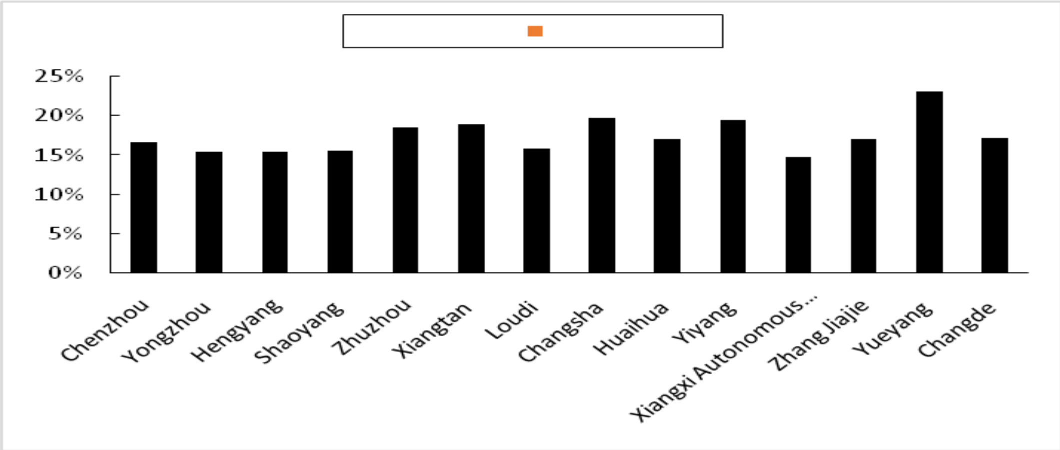

Figure 5. The average annual FPAR from 2001 to 2008 in Hunan

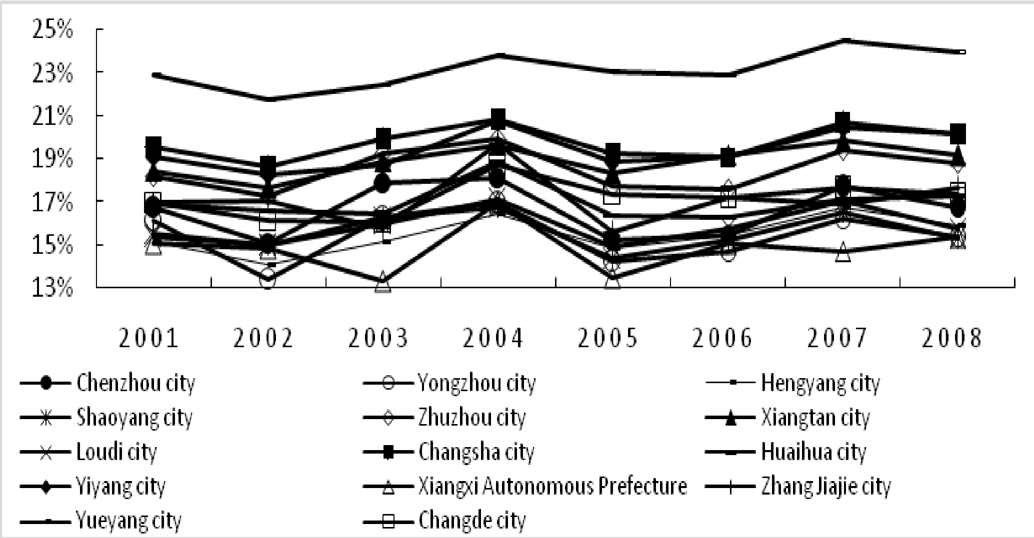

Figure 6. The average annual FPAR change curve of 2001-2008 in the states of Hunan province

From figure 5: Yueyang city's FPAR value is the highest, reaching 24%,Xiangxi Autonomous Prefecture FPAR value is at least, reaching 14%. There is a 10%difference between them. FPAR value from high to low ranking for Yueyang city, Changsha city, Yiyang city, Xiangtan city, Zhuzhou city, Zhang Jiajie city, Huaihua city, Chenzhou city, Loudi city, Shaoyang city, Hengyang city, Yongzhou city,and Xiangxi Autonomous Prefecture. The FPAR values of Yueyang city are the highest, because Yueyang city is located in Dongting Lake Plain, characterized by rich heat and fertile soil, blooming vegetation, high forest coverage rate and high grain crops; and Xiangxi Autonomous Prefecture were large mountainous areas, lower the amount of solar radiation and grain crop rate.

5.2 Spatial Variation of FPAR in Cities of Hunan Province

From figure 6, the trend of FPAR values in each state can be found to be almost consistent. FPAR values in all cities were at peak in 2004, while in 2002, except Zhang Jiajie city, Huaihua city, Xiangxi Autonomous Prefecture, the rest of the prefecture level cities were in the valley. The fluctuation of FPAR values in Xiangxi Autonomous Prefecture, Zhang Jiajie city, Yiyang city and Huaihua city were larger than other cities between 2001 and 2008, especially the relatively large fluctuations during 2003-2005, in a less volatile from 2006 to 2008.

The FPAR value of Yueyang city was the highest in Hunan Province, and was much higher than other cities. The FPAR value of 2004 and 2007 appeared to peak, while in 2002 and 2006, the value of the valley was in. The trend of change in Changsha city and Yiyang city were basic consistent. Before 2004, Changsha city's FPAR value was greater than Yiyang city, and the value of the two cities were almost equal in 2004. The gap between Changsha city and Yiyang city FPAR value were narrowed from 2004 to 2006, but Changsha city was still higher than Yiyang city; However, after 2006, the two cities FPAR value were basically equal. The trend changes of FPAR value in Chenzhou city, Xiangtan city and Zhuzhou city were similar, but the value of FPAR in Chenzhou city was far less than that of Xiangtan city and Zhuzhou city, and there was little difference on FPAR value between Xiangtan city and Zhuzhou city. The value of Zhuzhou city and Xiangtan city were close, and there was cross-distribution from 2001 to 2004. Before 2003, the value of FPAR in Xiangtan city was slightly higher than that of Zhuzhou city, but Zhuzhou city achieved a rapid rate of growth in 2002,and greater than Xiangtan city in 2003, while the two cities FPAR value were almost equal in 2004; From 2004, the FPAR value of Zhuzhou city has been greatly decreased, although there was a substantial increase from 2006 to 2007, but the value of FPAR in Xiangtan city was much higher than that in Zhuzhou city, and the gap was narrowed between two cities until 2007-2008. The change trend of FPAR in Huaihua city and Changde city was similar during 8 years. Before 2004, the FPAR value of Huaihua city was greater than that of Changde city, but after 2004, the FPAR value of the two cities were reduced and the FPAR value of Changde city was less than that of Huaihua city yet; The change of FPAR value of Changde city was not obvious, almost kept at the same level; After 2005, the FPAR value of Changde city was far higher than the city of Huaihua, but value of two cities reached unanimity in 2008. The change law of FPAR value in Zhang Jiajie city and Xiangxi Autonomous Prefecture were basically consistent, only except that the value of FPAR in Zhang jiajie city was far greater than that of Xiangxi Autonomous Prefecture. The line of Shao yang city and Loudi city almost overlap before 2004, showing that the value of two cities was basic equal, but after 2004, the value of Loudi city was a little higher than Shaoyang city. The fluctuation of FPAR value in Yongzhou city was bigger than Hengyang city. The value of Yongzhou city was much higher than the city of Hengyang in 2001, due to the sharp drop in 2002, FPAR value was slightly lower than Hengyang city, but rising substantial during 2002-2004, over Hengyang city; after 2004, it showed a trend of decline, and the value of FPAR in Yongzhou city was lower than Hengyang city.

From table 1: The FPAR was growing in most cities of Hunan Province in 8 years, and the growth rate of FPAR in Yiyang city was the fastest, and the growth rate was the highest, followed by Hengyang city, which was second in the province. Yueyang city ranked in third place. The average annual growth rate of Xiangtan city and Zhang jiajie city, Zhuzhou city and Changsha city, Loudi city and Huaihua city, Xiangxi Autonomous Prefecture and Changde city was close. Chenzhou city remained steady and had no growth, and Yongzhou city and Shaoyang city not only failed to growth, respectively -0.68% and -0.21% decrease each year instead. Fourteen cities in order of their average annual growth rate of FPAR: Yiyang city>Hengyang city> Yueyang city> Xiangtan city>Zhang Jiajie city> Zhuzhou city> Changsha city> Loudi city>Huaihua city>Xiangxi Autonomous Prefecture>Changde city> Chenzhou city>Shaoyang city>Yongzhou city. The average annual growth rate of FPAR in Yiyang city was the fastest, mainly due to the terrain of basin and the enough solar radiation; Yiyang city formally proposed the request of creating Forest City to State Forestry Administration in 2005, invested 2.65 billion yuan to develop forestry, so the vegetation coverage increased rapidly. The reason why the average annual growth rate of FPAR in Yongzhou city was negative growth was the high terrain, the relatively small amount of solar radiation; although the closing hill for afforestation and forest plantation project were been carried out from 1997, and achieved some results, but in 2008, forest volume of each unit area in Yongzhou city was far lower than the national existing savings, also lower than the current average level of Hunan province [22]. However, the unit farmland was showing an upward trend in the non-agricultural land. The terrain in Shaoyang city is the mountains and hills, and terrain is relatively high, less solar radiation; the vegetation types mainly for coniferous forest, natural forest vegetation-subtropical evergreen broadleaved forest almost being all destroyed by humankind. Afforestation project of afforestation of barren hills and due to the lack of subsidies, farmers enthusiasm after forestation is not high, tending and management of unmanned make inquire, resulting in afforestation of barren hills and ground clutter shrub clumps, livestock serious damage; And Shaoyang city suffered continuous severe drought between 2003 and 2004, greatly reducing the survival rate of the new seedlings. Since ancient times, Chenzhou city has been rich in forest resources, but with the rapid development of economy, the demand of forest resources is increasing and forest products industry developing rapidly.

Table 1. The FPAR change of Hunan province during2001-2008

city	Amplificat (%)	Average annual growth rate (%)
Chenzhou city	0	0
Yongzhou city	-4.65	-0.68
Hengyang city	5.05	0.71
Shaoyang city	-1.45	-0.21
Zhuzhou city	3.37	0.47
Xiangtan city	3.98	0.56
Loudi city	2.52	0.36
Changsha city	3.05	0.43
Huaihua city	2.28	0.32
Yiyang city	5.31	0.74
Xiangxi Autonomou Prefecture	2.07	0.29
Zhang Jiajie city	3.70	0.52
Yueyang city	4.87	0.68
Changde city	1.94	0.27

6. CONCLUSIONS

1) The total trend of FPAR value in Hunan province was on the rise from January to September, a downward trend from September to December; the high value of FPAR occurred in July and September, while the low value in February, the wave trough appeared in August. Summer was the season of the highest FPAR value of Hunan province, while winter was the lowest. The FPAR value fluctuated greatly from 2001 to 2008, and the peak value appeared in 2004 and 2007, which was the highest in 2004 during 8 years, the valley value respectively appears in 2002 and 2005, and the lowest value emerged in 2002 in those 8 years.

2) During the study period, the overall performance of FPAR in Hunan province was: Yueyang city>Changsha city>Yiyang city>Xiangtan city>Zhuzhou city>Changde city>Zhang Jiajie city>Huaihua city>Chenzhou city>Loudi city>Shaoyang city> Hengyang city> Yongzhou city> Xiangxi Autonomous Prefecture; the changes in the state was largely consistent in the past 8 years, that is, the highest value of FPAR was in 2004, while 2002 was the lowest. But Zhang Jiajie city, Huaihua city and Xiangxi Autonomous Prefecture rose small in 2002; the average annual growth rate of FPAR in each cities sorting for: Yiyang city>Hengyang city>YueYang city>Xiangtan city>Zhang Jiajie city> Zhuzhou city>Changsha city>Loudi city>Huaihua city>Xiangxi AutonomousPrefecture>Changdecity>Chen zhou city>Shao yang city>Yongzhou city.

ACKNOWLEDGMENT

The authors gratefully acknowledge the financial support education bureau of Hunan Province and China Academy of Sciences, through the research foundation of education bureau (Grant No. 13B027) and STS project (Grant No. D114D5) to conduct this study.

REFERENCES

1. Zhang Jian, Retrieval of FPAR Based on Energy Conservation Principle Using Remote Sensing, Master Thesis, Xi'an University of Science and Technology, 2014.
2. Li Gang, Wang Daolong, Fan Wenjie et al., Analysis on Temporal Variation of FPAR on Leymus Chinensis Meadow-steppes, *Theoretical Research*, vol.101, pp.10-15, 2009.
3. Li Gang, Study on Remote Sensing Estimation Models for FPAR/LAI of Temperate Grassland in Hulunber, Ph.D. Thesis, Chinese Academy of Agrieultural Sciences, 2009.
4. Li Jin, Zhang Degang, Zhang Hongbin et al., A Study on the Variations of Pivotal Photosynthetic Active Radiation Parameters of a Leymus Chinensis Meadow-Steppe in Hulunber, *Acta Prataculturae Sinica*, vol.19, pp.243-250, 2010.
5. Liu Hongshun, Observation and Calculation of Effective Radiation of Light, *Meteorological Monthly*, vol.6, pp. 5-6, 1980.
6. Xu Lijun, Tang Huajun, Zhang Hongbin et al., Temporal Variation of FPAR in the Alfalfa Pasture, *Pratacultural Science*, vol.28, pp. 562-566, 2011.
7. Yang Fei, Zhang Bai, Li Fengxiu et al., Diurnal Changes of Photosynthetically Active Radiation Parameters in Soybean and Corncanopies, *Chinese Joumal of Ecolog*, vol.26, pp. 1153-1158, 2007.
8. Guo Zhihua, Peng ShaoLin, Wang Bosun et al., Estimation of Radiation Absorption by Guangdong Vegetation Using GIS and RS, *Acta Ecologica Sinica*, vol.19, pp. 441-446, 1999.
9. Zhou Xiaodong, Zhu Qijiang et al., Interception of PAR Relationship between FPAR and LAI Insummer Maize Canopy, *Journal of Natural Resources*, vol.17, pp. 110-116, 2002.
10. Wu Bingfang, Zeng Yuan, Huang Jinliang, Overview of LAI/FPAR Retrieval from Remotely Sensed Data, *Advances in Earth Science*, vol.19, pp. 585-590, 2004.
11. Gao Yanhua, Chen Liangfu, Liu Qinhuo et al., Research on Remote Sensing Model for FPAR Absorbed by Chlorophyll, *Journal of Remote Sensing*, vol.10, pp. 798-803, 2006.
12. Yang Fei, Zhang Bai, Song Kaishan et al, Relationship between Fraction of Photosynthetically Active Radiation and Vegetation Indices, Leaf Area Index of Corn and Soybean, *Acta Agronomica Sinica*, vol.34, pp.2046-2052, 2008.
13. Li Jin, Variations of PAR Parameters and Validation of FPAR/LAI Model of Warm Steppein Hulunber, Master Thesis, Gansu Agricultural University, 2010.
14. Dong Taifeng, Meng Jihua, Wu Bingfang, Overview on Methods of Deriving of Absorbed Photosynthetically Active Radiation (FPAR) using remote sening, *Acta Ecologica Sinica*, vol. 32, pp. 7190-7201, 2012.
15. Ba Jialiang, Study on Estimating LAI and Fapar from Hyperspectral Data in Crop Canopy, Master Thesis, Hua Zhong Agricultural University, 2013.
16. He Jia, Liu Bingfeng, Li Jun, FPAR Monitoring Model Winter Wheat Based on Hyperspectral Reflectance at Different Growth Stages, *Transactions of the Chinese Society for Agricultural*, vol.46, pp. 1000-1298, 2015.
17. Huang Hui, Study on the Ecological Security of Hunan province, Master Thesis, Central China Normal University, 2013.
18. Jiang Hongxing, Forestry Survey of Hunan Year book [EB/OL].
19. Ma Yanhui, Lin Hui, Sun Hua, Variation Analysis of Different Forest Types Vegetation Index in Hunan Province, *Research of Soil and Water Conservation*, vol.17, pp. 217-221, 2010.
20. Wang Xiaolan, Li Xiangyu, Li Zuxian et al., Analysis of Freezing-hazard Event in 2005 in Hunan Province, *Meteorological Monthly*, vol.32, pp. 88-91, 2006.
21. Ding Xiaojian, Yang Jun, Tang Minghui et al., Characteristic Formation Analysis on Two Typical Freezing Disaster Weather Events in Hunan Province, *Joumal of arid Meteorology*, vol.28, pp. 76-80, 2010.
22. Deng Dongfa, Yuan Yaguang, Current Situation and Suggestion of Forest Protection and Utilization in Yong Zhou City, Hunan Forestry Science and Technology, vol.35, pp. 90-92, 2008.
23. Jiang Chong, Zhu Feng, Yang Chen et al., Distribution and Change of Photosynthetically Active Radiation (PAR) in the Northern and Southern Regions of Qinling

Mountains, China, *Progress In Geography*, vol.32, pp. 435-446,2013.

24. Li Gang, Xin Xiaoping,Fan Wenjie et al., Spatio-Temporal Variation in the Key Photosynthetic Parameters of Grassland in Inner Mongolia, *Resources Science* , vol.30, pp. 1374-1381, 2008.