A DETAILED STUDY ON GPS AND GIS ENABLED AGRICULTURAL EQUIPMENT FIELD POSITION MONITORING SYSTEM FOR SMART FARMING

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Abstract. To develop refined agriculture and improve Agricultural productivity, a new monitoring system has been proposed in this paper. Based on the actual situation of early agriculture and the actual national conditions of China, Geographic Information System (GIS) technology and Global Positioning System (GPS) technology have been combined. Based on the combination of GIS technology and GPS technology, the results show that the position of field vehicles can be displayed in the electronic MAP in real time within 5% error. On this basis, Agricultural production and cultivation can be realized, and the monitoring system can realize the real-time display of vehicle location in the field on electronic MAP to guide production and cultivation. The static test shows that the positioning accuracy of the four GPS receivers is the worst, and the positioning accuracy of MAP330 receiver and GPS25 receiver is better. However, the positioning accuracy of AGl32 receiver is the highest with the 0.37m error when compared with the error of 1.2m of other machines. Using GPS to measure the area, the error of farmland area and farmland side length is less than 5%, and the precision AGl32 receiver for precision Agricultural measurement is also improved with the proposed model.

Key words: Precision agriculture; GPS technology; GIS technology; Agricultural equipment; Monitoring system

AMS subject classifications. 68U35

1. Introduction. Precision agriculture applies automatic control theory, intelligent decision-making, GIS and GPS technology. It integrates variable seeding, online real-time yield measurement, variable rate fertilization, variable irrigation, variable rate spraying and other technologies into a whole, so that the economic benefits of Agricultural operations are rapidly improved [1]. Recently, the precision agriculture made it possible to increase the productivity and ease in the agribusiness to the farmers which leads to the profitable crop yield for the farmers. The technological effrts made with the help of precision agriculture in the planning of reap the crops, in time spray of pesticides, treatment to protect the crops and study the environment to maximize the yield of crop. With the help of these important planning measures, the overall significant growth has been visualized in the study [2]. The use of precision agriculture has significantly got attention due to the use of high ended agriculture equipment's performance and sufficient increase in the profit of crop yielding in term of agribusiness [3]. The easy to use methods and timely planning added gems in it. The involvement of GPS in precision agriculture made it more cost effective, accurate and easy. The study of agriculture field using sensors such as humidity, temperature, crop growth, GPS precision are the major factors toward smart farming. Initially, it was analyzed that the use of sensors and precision agriculture can be applied to large Agricultural land but as the technology advanced with time it has made it possible to use in any kind of farms. The attraction toward precision agriculture may be due to the availability of easy to use and cheap Agricultural equipment to all farmers. The study of agricultural land using GPS, GIS and remote sensing made it possible to manage water availability, seeds, fertilizers, pesticides, and accurate crop yield time which leads to increase in farming crop yielding efficiency and reduction in the overall cost of farming [4]. Recently, numbers of Agricultural tools have been developed to manage the crop yielding using crop data processing and real-time data management for the smart farming and agribusiness [5]. The improvement in the sensors technology for fast and accurate data processing management also helped the increase in the use of precision agriculture [6]. Nowadays, all aspects of precision Agricultural can operate normally, which benefits from the correctness of information collection and processing and the fast and accurate real-time communication [7].

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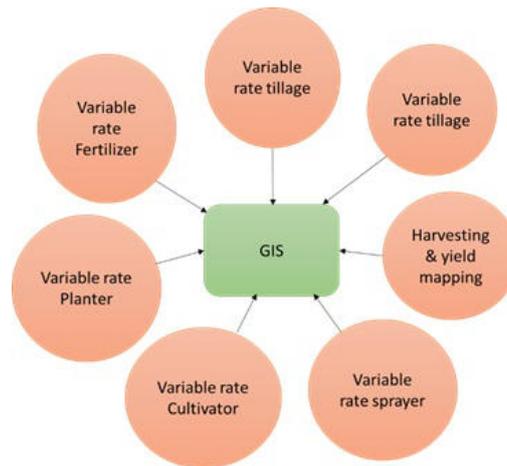
Fig. 1.1. *Precession farming overview*

The important foundation of precision Agricultural is to collect and update the spatial variable information that affects crop growth environment [8] quickly and effectively. The use of GPS enabled the smart farming with the management of area of crop yield, road/route management, and area of interest for faming from remote location. The data collection using sensors and camera to study the impact of pests in the farmland is also made possible using precision agriculture [9]. The use of drones to spray pesticides at specific farmland without interventions of human is also an important application of use of GPS and GIS technology in precision agriculture [10]. The development of several online applications for precision agriculture has boosted its use in smart farming. Several efforts are made to improve the GPS technology and remote sensing; various technological efforts have been made on GPS satellites communication [11-13].

1.1. Contribution. The basic unit of evaluating Agricultural operation benefit and unified planning of crops is farmland plot, so the key to improve Agricultural productivity is to collect and process information data effectively, quickly and comprehensively. If the above conditions are met, the adverse effects of Agricultural labor shortage can be reduced. If the problem of positioning information is solved, the problem of moving Agricultural machines and the problem of making machines complete other tasks will be solved easily.

1.2. Organization. The rest of the paper is organized as follows: A detailed literature is discussed in the Section 2. The development of various standards and systems are discussed in the Section 3. Section 4 is used to explain the system setup and result discussion. In the last Section 5, a conclusion is drawn.

2. Literature Review. Due to the great breakthrough of monitoring technology, many international Agricultural equipment manufacturers have launched their own intelligent variable controller, intelligent output monitor. ISI launched the wire LWSS lnfo project (1998 2003) to create a more advanced Agricultural and forestry management multimedia service system [14] by using High Speed Data Communication System (HSDCS) / Global System for Mobile Communications (GSM) / General Packet Radio Service (GPRS) wireless communication technology. Du Yongxing studied the development direction and feasibility of Information Technology (IT) application in Agricultural field [15]. Zhang Han et al. studied the technology of a satellite broadband wireless access system, which meets the requirements of real-time processing and high-speed transmission of cotton pest multispectral images, and improves the effectiveness and efficiency of variable operation of dispensing machinery[16]. Zhang Yali et al. developed the remote monitoring system "tetrad" for livestock transportation process, using GSM wireless technology [17]. Nowadays, France, Britain, Germany and other countries have basically realized the network management and automatic control [18] of light, humidity, spraying, fertilization, temperature and so on in Agricultural production. In recent years, with the support of national government, the development of remote Agricultural equipment and remote Agricultural monitoring system is relatively fast. Nowadays, many classic monitoring systems have been used in Agricultural operations,

such as humidity, temperature and light, as well as the network management and automatic control of sowing, fertilization, spraying and harvesting in Agricultural production [19]. The growth conditions of crops can be regulated by the monitoring and control system to reduce growth cycle, optimize product quality and increase crop yield, so as to improve economic benefits. Some monitoring and control systems also have the function of warning [20]. As long as the lower limit and upper limit of monitoring factors are set, the expert system can automatically adjust and control the system to achieve early warning effect. As early as 1980, precision Agricultural was proposed in the United States, and intelligent monitoring technology was promoted by its development of microelectronics technology. The early technology foundation of precision Agricultural was composed of cultivation management, soil testing and formula fertilization, crop growth simulation and other Agricultural expert systems [21]. From 1995 to 1996, precision Agricultural technology experiment was carried out in a farm in Alabama. Using GPS to guide fertilization can greatly reduce the use of chemical fertilizer for crops, increase the yield by about 40%, and greatly improve the economic benefits [22]. At present, the United States has applied high and new technologies such as GPS monitoring operation in Agricultural equipment such as grain combine seeder, sprayer, harvester and fertilizer. In Western European countries, the production links of corn and wheat, such as soil preparation, sowing, harvesting and transportation, have been fully mechanized, and many precision Agricultural operations of Agricultural machinery have been realized with GPS system.

In this paper, the precision Agricultural monitoring system based on GIS technology and GPS technology includes the following aspects: position positioning and navigation, control machine, data collection, data transmission and data processing. Its design idea is to establish a mobile terminal to collect data (connected by GPS receiver and computer terminal), convert the collected farmland information (including temporal information and spatial information) into data, and then package it into a file and transmit it to the control and detection center. If GSM mobile communication network is used, SMS mode can also be used to transmit the data, which will edit the collected farmland information data into SMS form for data transmission. Firstly, the collected Agricultural field information is stored as the data exchange file, which is the way to transfer the data file, and the data exchange file is transferred to the monitoring and updating service center. The application of monitoring technology and remote information collection in Agricultural system can realize precision Agricultural operation, intelligent Agricultural operation and automatic Agricultural operation.

3. System Design and GPS Test.

3.1. Overall structure design of the system. The field vehicle monitoring system based on GIS technology and GPS technology is that the data sent by satellite is received by GPS receiver, and then the radio connected by radio antenna is transmitted to the monitoring center through modem [23]. The monitoring center transmits the data to the central server, and the final data processing is completed by the GIS monitoring system of the central server. The schematic diagram of the real-time monitoring system for field operation tools is shown in figure 3.1.

3.1.1. Overall system composition . The system consists of the following parts: system software, PS satellite, GPS mobile terminals (n), computer, radio and monitoring center station. The software of field vehicle monitoring system based on GIS and GSP technology includes the following three parts [24].
- Network communication subsystem.
- MAP management subsystem.
- Serial communication subsystem.

The system composition is shown in figure 3/2. The integrated development environment and operating system used in system software development are as follows. The Development tools areAccess2000 MAPInfo7.0; VisualBasic6.0; Photoshop6.0; MAPx4.5. Further the Operating environment: Windows9X/Windows Me/ Windows200 and Windows 2000 Professional.

3.1.2. System operation process. In order to obtain GPS positioning information, GPS monitoring system should use GPS receiving equipment to transmit the processed data to the monitoring control center by wireless communication, and display it on the electronic MAP provided by GIS platform [25]. In addition, GIS platform is used to process the obtained data. However, the operation process of the system is complex, and only GPS signal transmission is described in this paper. In this way, the workflow can be expressed intuitively and easily understood. The order of work is given in figure 3.3.
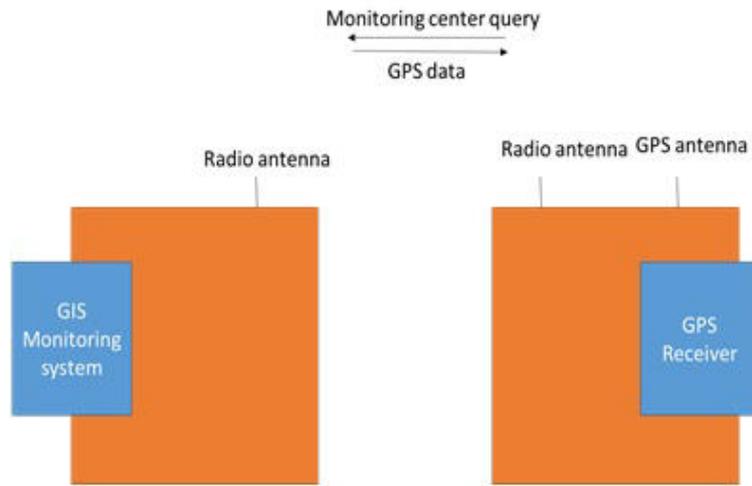
FIG. 3.1. *Schematic diagram of field tool synchronization monitoring system*
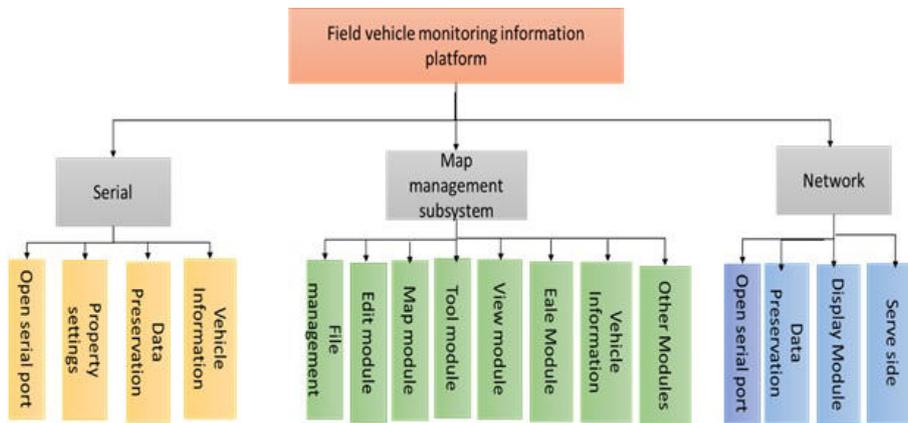
FIG. 3.2. *Composition of monitoring system*

TABLE 3.1
Requirements for positioning accuracy and operation type

Job type	Positioning requirements
Sampling survey	100-1000m
Variable rate fertilization	30-50m
Survey the yield	10-15m
Variable spray	1-1.5m
Construction of seed bed	5cm

3.2. Field GPS Positioning Test. The corresponding relationship between positioning accuracy and operation type is shown in Table 3.1. GPS has the advantages of convenient, real-time and fast positioning of farmland information, but there are many interference factors in the measurement, such as positioning error. Therefore, in order to meet the performance requirements of GPS operation [25].

3.2.1. Static positioning test of GPS receiver. In this test, four different types of GPS receivers are used for static positioning of the same position. In order to compare the positioning accuracy of these
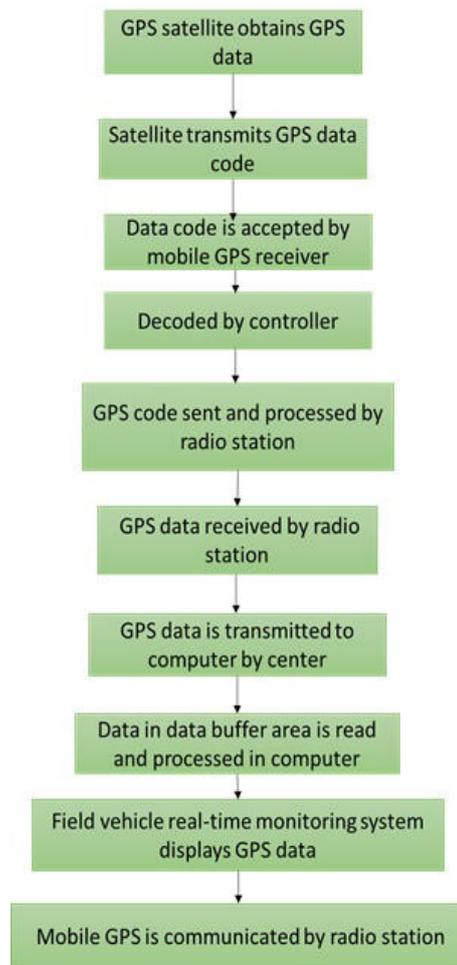
FIG. 3.3. *Order of work to monitoring system*

four GPS receivers, the time of this test is set as 3 min. The four types of GPS receivers are the OEM GPS receiver GPS25 of Garmni Company, the handheld GPS receiver MAP3 and MAP330 of M25lean Company, and the Agricultural differential GPS receiver AGl32 of American tremble company [26]. Only AGl32 uses differential method for positioning, others use non differential method. The longitude and latitude distribution of positioning data of AGGPSZ32 receiver, MAP315 receiver, MAP330 receiver and GPS25 receiver are shown in figure 3.4, 3.5, 3.6 and 3.7. It can be seen from the figures that the observed data are moving in a certain way.

3.2.2. GPS distance area test. Use a tape measure to measure a rectangular area with a length of 50.04m and a width of 28.04m. Two methods are used to measure the four vertices a, B, C and D of the rectangle. It is the first method to measure four points a, B, C and d by static measurement. The coordinates of the four points are taken as the average of the measured values, and then the area and the length of each side are calculated respectively [26]. Moving along a-b-c-d with GPS receiver in hand is the second measurement method. The coordinate values of a, B, C and D are the coordinates of intersection points of each side. Finally, the area and side length are calculated.

4. Results and Discussion.

4.1. Overall design analysis. The field vehicle monitoring system based on GIS technology and GPS technology has the following functions [27-32]:
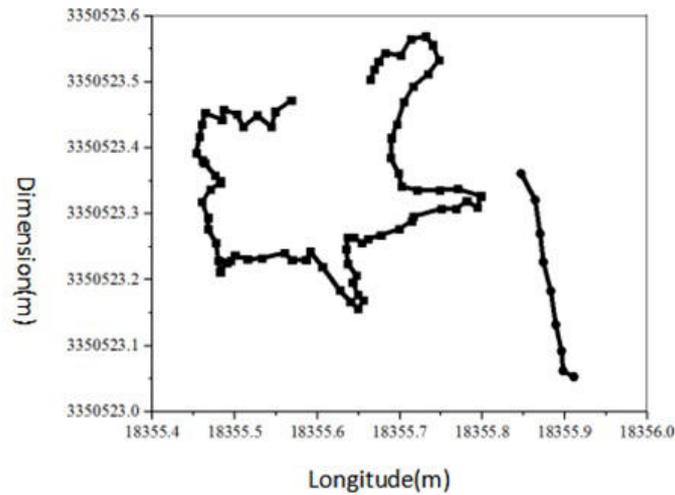
Fig. 3.4. *AGGPSz32*
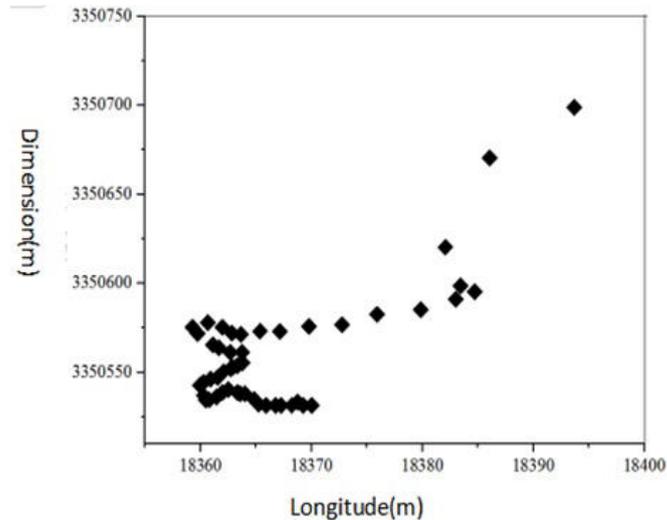
Fig. 3.5. *MAP315*

- The MAP management software has the function of MAP editing and processing, which can easily complete the MAP operation through shortcut keys, such as creating thematic MAP, various operations of layer, MAP tool operation and so on.
- Using the program written by Visual Basic 6.0 to read the data received by the central station. The information will be displayed by the mobile center.
- The mobile terminal sends the status back to the central station.
- Real time display the position of the moving end of the field vehicle in the electric MAP.
- The mobile terminal has query function in the central station.

In order to better complete the task of monitoring field vehicles, the following problems should be solved: the design of multi-target monitoring program for network transmission; the display of mobile terminal position on the electronic MAP; the receiving and decoding of GPS signal [33]. In order to solve these problems, we have carried on the software design, this design uses VB6.0 and MAP4x, realizes the network transmission multi-target monitoring; uses MAPX to embed in the VB environment to realize the mobile terminal position on the
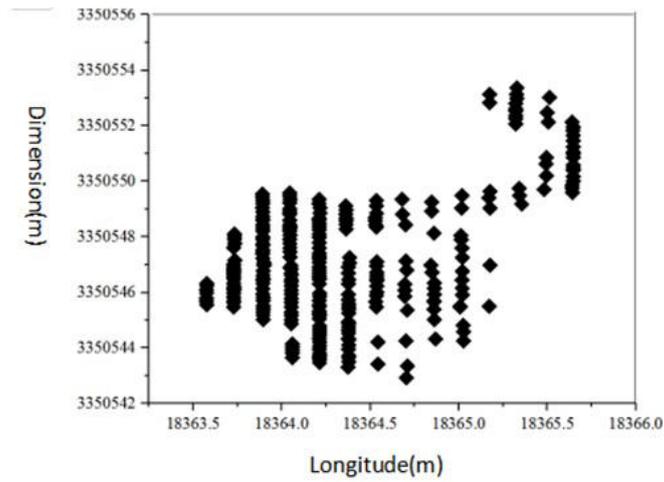
Fig. 3.6. *MAP330*
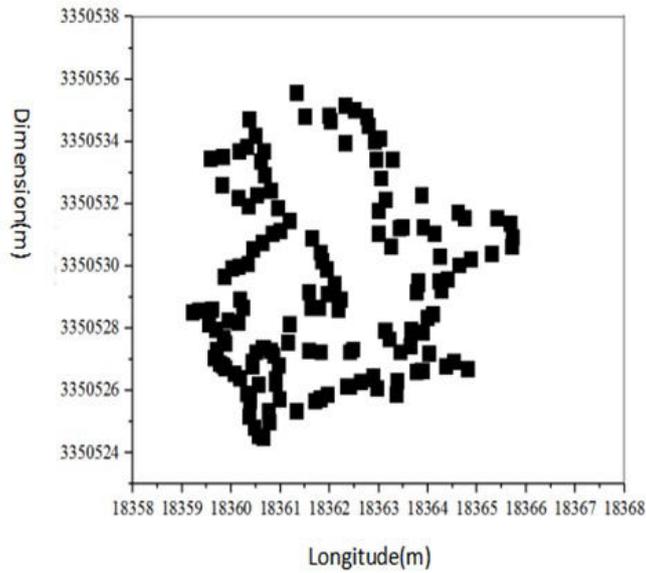
Fig. 3.7. *GPS25*

electronic MAP display; uses VB to make wislock control and MS Comm control to complete the receiving and decoding of GSP signal.

4.2. Test analysis of GPS. The OEM GPS25 receiver developed by American Garmin Company is used as the receiver of this test. It has the advantages of light weight, low power consumption, small size and easy to carry. Its main performances are as follows [35].

- Working current: 200 Ma.
- Working voltage: ± 5 VDC, ± 5%.
- Positioning accuracy: 5 m (differential mode), 15 m (without SA), 100 m (SA).
- Hot start time: 15 s, cold start time: 45 s.
- Data format: nmea-0183v2.0ascll standard.
- Channel number: able to track 12 satellites at the same time.

TABLE 4.1
GPS data analysis

TYPE	AG132	OEM-25	MAP315	MAP330
COUNT	1744	1787	964	1106
$\bar{X}$	18356.0764	18362.7626	18361.9835	18364.0548
$\bar{Y}$	33350523.3321	3350529.5164	3350543.4410	3350547.8589
2σ	0.147	1.6727	2.6359	0.6075
S_x	0.118	2.4940	9.0779	2.2163
S_y	0.3696	6.0060	18.9057	4.5961
ΔX	0	6.6862	5.9071	7.9784
ΔY	0	6.1848	20.1089	24.5268

TABLE 4.2
GPS sampling interval

GPS	AG 132	MAP 330	GPS 25	MAP 315
Error (m)	0.3696	4.5961	6.006	18.9057
Recommended distance (m)	7.392	91.922	120.12	378.004

- Interface form: dual channel RS-232 compatible serial interface.
- Differential positioning function.

The positioning data analysis table of several GPS receivers is shown in Table 4.1. The number of data records in the table is count; the standard deviation is S_x, S_y; the mathematical mean of the observed data was $\bar{X}, \bar{Y}$; positioning error is 2σ. The mean value was 0 ΔX and ΔY The deviation of positioning mean was AGl32. According to figure 2, the highest positioning accuracy is AG132 receiver, and the error is only 0.3696m.The accuracy of the four GPS receivers is as follows [36]: MAP 315 receiver < GPS25 receiver < MAP330 receiver < AGl32 receiver. According to the absolute positioning error, MAP 330 receiver < MAP 315 receiver < GPS 25 receiver < AGl32 receiver. Absolute error is the common modulus in farmland positioning measurement. It has little influence on relative positioning error, or can eliminate these errors [37-39]. Therefore, the performance of GPS receiver should be measured by relative positioning error. Therefore, the author discuss that the positioning accuracy of MAP315 is the worst, that of MAP 330 is better, and that of AGl32 is the highest. As shown in Table 4.2, the minimum distance of the positioning sampling point is calculated within 5% of the allowable positioning error.

4.2.1. GPS distance area test. Three groups of mobile dynamic positioning and two groups of static positioning are included in the GPS positioning data distribution MAP. Dynamic 1, dynamic 2 and dynamic 3 move in the order of a-b-c-d-a. Taking 120 seconds as the cycle of each group, the test was carried out in the order of dynamic movement test 1 dynamic movement test 2 dynamic movement test 3.

The measurement time of each point in static test 1 is about 300s, in which a, B and D are measured according to time, and point C is measured the next day; in static test 2, there is about 30min measurement time between each point, and a, B, C and D are measured in time sequence. It can be seen from the figures of dynamic movement test 1, dynamic movement test 2 and dynamic movement test 3 gradually move to the upper right corner, indicating that random error is not the main error of GPS positioning. Its error is mainly related to the movement time. Therefore, in the dynamic motion measurement, acceleration measurement can greatly reduce the influence of drift error, and then improve the measurement accuracy.Except for static 1, the other four groups have similar measurement patterns, and the difference between dynamic measurement and static measurement is not very big.3. In static 1, the main error is caused by point C. due to the short positioning time in static test 1 and the C point tested the next day, the C point has a large deviation. Therefore, continuous measurement should be made for the measurement of farmland area and the distance of farmland side length, and the measurement time should be longer.

TABLE 4.3
Calculation of distance area

Error	Static 1	Static 2	Move 1	Mobile 2	Move 3
AB (m) error	30.73-4.09%	31.54-1.56%	30.75-4.03%	31.4-2.00%	32.11+0.22%
BC (m) error	28.23+0.53%	27.72-1.28%	28.2+0.43%	28.42+1.21%	27.26-2.92%
CD (m) error	36.10+12.7%	31.55-1.53%	31.12-2.87%	30.88-3.62%	31.26-2.43%
DA (m) error	26.44-5.84%	27.57-1.82%	28.06-0.07%	27.93-0.53%	27.98-0.36%
S (m2) error	913.40+1.52%	871.43-3.14%	870.20-3.28%	873.94-2.86%	875.14-2.73%

The side length and area of the rectangle can be calculated by GPS positioning time and data. Table 4.3 shows the calculation results. It can be seen from table 4.3. Except for static experiment 1, the area measured by other groups of experiments is smaller than the actual area. This experimental phenomenon is caused by the system error, so the correction coefficient should be added to the actual measurement area to eliminate the system error. From the error between the data measured in the table 4 and the actual data, it can be seen that the actual measurement accuracy of the static experimental measurement and the dynamic moving measurement is almost the same. However, compared with the experimental time, we need to spend more time on the static experimental measurement. Therefore, in the daily fine Agricultural operation, it is recommended to use the dynamic moving method to measure the farmland area and the farmland side length. Except for the static o, the errors of the area and side length of the other groups are within 5%, and the measurement accuracy can meet the requirements of precision Agricultural measurement. In static test 2.4.2, 4.59 m is the positioning error of MAP 330. However, in this distance test, except for static experiment 1, 1.29M is the largest experimental error, and the maximum relative error is as low as 4.03%, and the measurement accuracy has been greatly improved. Therefore, although it takes a long time to measure the distance, the distance between the two points actually has a difference effect, so the effect is still greatly improved.

5. Conclusion. The research and practice of precision Agriculture in China is still in the primary stage. In order to meet the requirements of modern agriculture, such as "protecting the environment, saving resources, reducing investment, increasing production", etc. Based on China's national conditions, the corresponding Agricultural operation information management system is established, which is of great significance for the sustainable development of Agricultural production in China. In this paper, how to establish the system is discussed, including the application background of the system, the overall scheme of the system, and the field test of GPS. According to the static test of GPS, the positioning data can change with the change of time, and its positioning data arrangement is not accidental. The static test shows that the positioning accuracy of the four GPS receivers is the worst, and the positioning accuracy of MAP330 receiver and GPS25 receiver is better. However, the positioning accuracy of AGl32 receiver is the highest, and the error is only 0.37M. Compared with the error of 1.2m of other machines, its accuracy is much higher. Using GPS to measure the area, the error of farmland area and farmland side length is less than 5%, and the precision AGl32 receiver for precision Agricultural measurement can meet the requirements. In area measurement, the accuracy of static positioning measurement is similar to that of dynamic moving measurement. However, due to too much time consumed in static measurement, it is better to use dynamic moving mode to measure the area. Because the static measurement takes a long time, it is recommended to use the dynamic moving method to measure the area. This experiment was constrained by many conditions, and it was not carried out in more and larger fields, so it is not completely accurate. The experiment can be supplemented and improved in the future.

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