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Determination of GPS-Based Land Leveling System Performance in Land Conditions

Arazi Koşullarında GPS Tabanlı Arazi Tesviye Sisteminin Performansının Belirlenmesi

Bahattin Akdemir [1]

[1]*Tekirdağ Namık Kemal Üniversitesi, Ziraat Fakültesi, Biyosistem Mühendisliği Bölümü, Tekirdağ, Türkiye.*
** Corresponding author (Sorumlu Yazar): B. Akdemir, e-mail (e-posta): bakdemir@nku.edu.tr*

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ABSTRACT

The purpose of this research was to determine performance of the GPS levelling system which has recently started to be used instead of laser system with levelling shovels widely used in rice farming. Levelling system with GPS, reference station, rotating laser, levelling shovel and tractor were used as material. The width of levelling shovel was 6 m. The GPS levelling system manufactured by a local manufacturer, includes the screen, GNSS Antenna At360 and UHF antenna. The GPS levelling system was operated from a reference station that broadcasted a position correction signal. A Broadcasting device with 2 Wat Lora was used as the reference station. The land tests were carried out with a 128 kW tractor. The laser level detection device was TOPCON RL-H3A to determine the heights according to the levelling plane. Deviations from the reference plane were determined. At the same time, the elevation heights of these points were determined by GPS. The deviation values of the obtained data from the targeted values were calculated and evaluated by taking into account the tolerances. Measurements were also evaluated by calculating the Root Mean Square Error (RMSE) value. Average value of the measurement was determined as 5.71 mm, the standard deviation value was calculated as 3.48 mm and the mean square error was 0.262 mm. The leveling tolerance in the pans for rice production was determined as 2 cm with farmers' interviews. Most of the measured data were below than 10 mm. As a result of both the measurement data and the evaluation from the graph and field observations; the GPS levelling system has successfully levelled the land within acceptable limits.

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ÖZET

Bu araştırmanın amacı, çeltik tarımında yaygın olarak kullanılan lazer sistemli tesviye küreği yerine son zamanlarda kullanılmaya başlanan GPSli tesviye sisteminin performansını arazi koşullarında belirlemektir. Araştırma materyali olarak GPS'li tesviye sistemi, referans istasyonu, döner lazer, tesviye küreği ve traktör kullanılmıştır. Tesviye küreğinin genişliği 6 m'dir. Yerli üretici tarafından üretilen GPSli tesviye sistemi, ekran, GNSS Anten At360 ve UHF antenden oluşmaktadır. GPSli tesviye sistemi, konum düzeltme sinyali yayınlayan bir referans istasyonundan konum verileri alınarak çalıştırılmıştır. Referans istasyonu olarak 2 Wat Lora'lı bir Yayın Cihazı kullanılmıştır. Testler 128 kW'lık bir traktör ile gerçekleştirilmiştir. Tesviye düzlemine göre yükseklikleri belirlemek için TOPCON RL-H3A lazer seviye tespit cihazı kullanılmıştır. Referans düzlemine göre sapmalar belirlenmiştir. Aynı zamanda bu noktaların kot yükseklikleri GPS ile belirlenmiştir. Elde edilen verilerin hedeflenen değerlerden standart sapma değerleri toleranslar da dikkate alınarak hesaplanmış ve değerlendirilmiştir. Ölçümler, kök hata (RMSE) değeri hesaplanarak değerlendirilmiştir. Ölçüm noktalarından elde edilen ortalama değer 5,71 mm, standart sapma değeri 3,48 mm ve RMSE 0,262 mm olarak hesaplanmıştır. Çiftçilerle yapılan görüşmelerde pirinç üretiminde tavalardaki tesviye toleransı 2 cm olarak belirlenmiştir. Ölçülen verilerin çoğu 10 mm'nin altındadır. Hem ölçüm verileri hem de grafik ve arazi gözlemlerinden yapılan değerlendirmeler sonucunda; GPS tesviye sistemi araziyi kabul edilebilir sınırlar içerisinde başarıyla tesviye etmiştir.

1. INTRODUCTION

Irrigation water is applied to the soil by flowing over the soil surface in surface irrigation methods. Irrigation water should be applied to the root area of all plants equally and without loss and without causing soil erosion. This only depends on the soil surface having a certain slope degree and having a smooth surface. Such a surface can only be provided by leveling the land. In lands with irregular soil surfaces, water accumulates more in hollow points and less at higher elevations. The high points of fields sometimes do not receive any water. Lands with high slopes, on the other hand, are subject to soil erosion by irrigation water. Both situations cause a decrease in productivity. In areas without drainage, excess water accumulates in hollow points, resulting in a rise in the ground water level and therefore a salinity problem. In order to avoid all these problems, the surface of agricultural lands should be made suitable for irrigation with a smooth and appropriate slope, i.e. leveled (MEB, 2015).

Geographical Information Systems (GIS) were investigated for determining the different levelling plane slopes and cut and fill volume in a research. GIS supported results were compared with the traditional methods for land levelling. More reliable results were obtained by using Geographical Information Systems (GIS) for calculation cut and fill volumes and achievement of more efficient and easier database creation and design was realized (Demirtaş, 2004).

A field experiment was carried out to compare performance of a modified laser scraper and unmodified scraper. Modification consisted of adding 8 chisel shanks on the main frame of the scraper set at equal distances along the width of the scraper. The objective of the modification was to eliminate firm, unchiselled, spots that normally appear during levelling with the unmodified laser scraper. Levelling was performed at 0% and 0.03% slopes. Results of the levelling at 0% slope with the modified laser scraper in a more homogeneous than with the conventional scraper (El-Shikha et al., 2008).

It is now possible to determine the position of the bucket teeth of an excavator or shovel within a few centimetres with GPS and rapid response tilt sensors. Applications include selective mining, bench control, precise excavation and placement of spoil, bench and ramp control, excavation of civil structures and production measurement (Seymour, 2015).

An intelligent integrated control terminal was designed for farmland levelling positioning based on RTK-GNSS. The integrated control terminal consists of a GNSS receiver module, a valve control module, a scraper load monitoring module, a core processing module and a touch screen. The core processing module calculates and analyses the terrain data from the GNSS receiver module and the scraper load data. Management software and integrated control terminal was tested in fields. The integrated control terminal was stable and reliable according to the test results (Niu et al., 2014).

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It is now possible to determine the position of the bucket teeth of an excavator or shovel within a few centimetres with GPS and rapid response tilt sensors. Applications include selective mining, bench control, precise excavation and placement of spoil, bench and ramp control, excavation of civil structures and production measurement. A paper will discuss the hardware and software capabilities and include actual case studies of applications (Seymour, 2015).

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An automatic navigation land levelling system based on the global navigation satellite system (GNSS) and an inertial navigation system (INS) was developed to improve the efficiency and accuracy of land levelling. The navigation experimental results showed that the average root mean square error (RMSE) of the tractor and the scraper were 2.94 cm and 3.15 cm in tracking a straight path and 8.61 cm and 9.83 cm in tracking a curved path, respectively. The average RMSE of the path tracking was reduced by 75.2% and 67.4% for the tractor and the scraper, respectively. The GNSS/INS-based automatic navigation land levelling system can notably reduce the lateral position deviations, improve the control accuracy and land levelling efficiency (Jing et al., 2023).

An adjustable land levelling equipment was designed. The reference elevation of the land to be levelled was generated based on the topographic data acquired by the RTK-GNSS technology. Blade lifting mechanism was controlled by comparing the reference elevation, the real-time blade's elevation and attitude data which was obtained by the dual antenna GNSS receiver. As a result, the land levelling operation was implemented. An algorithm using the electro-hydraulic proportional control technology was developed for adjusting of the blade's height. The GNSS land levelling equipment can have a good land levelling quality (Fu et al., 2016).

Determining deformations using geodetic methods was examined. In order to perform the deformation analysis, the measurement data of a real engineering structure was simulated, taking into account the principle of preserving the project data. The main aim of this study was to determine the deformations that occur in large-surface engineering structures within engineering structures that have many different structural characteristics. Programs that can evaluate the data will be used while determining the deformations (Uçaker, 2021).

A research was carried out on the strength-based computer aided design of a hydraulically effective soil excavation machine (scraper). After the design outputs obtained, a three-dimensional 1:15 scale prototype model of the machine was manufactured using the additive manufacturing technique, and the design was physically evaluated and the manufacturing/technical drawings were prepared, where the first prototype in 1:1 scale could be manufactured (Eravcı, 2022).

Power requirements and maximum working depths were determined for the laser-controlled levelling machines and tractor. In the combination of the laser-controlled levelling machines and tractor with the same working width, an increase in the working depth was observed as the tractor power and speed increased. The data indicated that it was necessary to calculate the maximum depths of work for determining the power demands according to the different tractor powers sold and LKTM combinations of different working widths (Akgül, 2020).

A study was carried out with laser land levelling (T1) and control (non-levelled) (T2) on clay loam soil. The laser leveller (Leica MLS700) was used hitching with a TAFE tractor. Elevation data was collected from the different points of the field. The maximum gage reading was 247.0 cm and the minimum gage reading was 219.2 cm. Average gage readings of the laser levelled plot was 235.66 cm that was settled for auto adjustment. Finally, an equal gage reading of 235.66 cm was observed after levelling the plot (Hoquel and Hannan, 2014).

A laser leveller was developed for paddy field use, which, in addition to an ordinary laser levelling system, features a specially designed 5 m long harrow towed by a tractor through a hydraulically driven 3-point linkage and a levelling control system used to control the height position of the harrow. The mechanical design and electrical control flowchart were presented in this research. The whole system works fine as shown by extensive field tests (Luo et al., 2007).

Application of intelligent navigation technology is explored in order to improve the efficiency of GNSS-controlled land levelling system. Load of forklift was real-time monitored. In this case, the GNSS-controlled land levelling system with the function of intelligent navigation was much more efficient, intelligent and time-saving (Wang et al., 2014).

GPS/Levelling geoid determination method and mathematical models, used in geoid determination with this method were investigated in a research (Kaloop, 2005).

The purpose of this research was to determine the performance of the GPS levelling system, which uses coordinate data obtained from GPS, which has recently started to be used instead of laser system in levelling shovels widely used in rice farming. In the research, a domestic production system was tested and the obtained data was evaluated.

2. MATERIALS AND METHODS

2.1. Materials

Materials were levelling system with GPS, reference station, rotating laser, leveling showel, tractor, field.

2.1.1. Levelling shovel

In the tests, a 6 m working width leveling shovel made by Ege Sebat and Çekiçkesen was used (Figure 1). The technical specifications of the leveling shovel are given in Table 1.

Figure 1. Leveling shovel

Table 1. General technical specifications of leveling showel

Working Width	*Weight*	*Transport width*	*Length*
6000 mm	3200 kg	2850 mm	6300 mm

2.1.2. Levelling system with GPS

The GPS leveling system manufactured by local manufacturers, includes the screen, GNSS Antenna At360, UHF antenna, valve cable, power cable, GNSS antenna cable, hand joystick and mounting apparatus (Figure 2). Technical specifications of which are given in Table 2 below. Detailed information about GPS leveling system, reference station (RTK BASE Station), leveling shovel, tractor, test field, laser measuring system, GNSS device were explained below.

Figure 2. Levelling system with GPS

Table 2. Technical specifications of the GPS leveling system

T1000 GNSS Tablet	***/ LM 1000 GNSS ANTENNA***
GPS	L1, L2
GLONASS	L1, L2
BDS	B1, B2
GALILEO	E1, E5b
QZSS	L1, L5
SBAS	WAAS, EGNOS, MSAS, GAGAN
RTK accuracy	H-10 MM1 mm
Measurement sensitivity	V-15 mm +1 pmm
Data format	RTCM V2.3/3.0/3.2, NMEA0183
Data tranfer frequency	20 Hz
Leveling accuracy	5-10 mm (for base reference station)

When the RTK system or base station was placed and activated, the device (LM1000) was turned on. After the WiFi signal on the screen was activated, the leveling shovel blade put on the ground in the field. On the menu, press the "ELEVANCE-RESET" button, take the measurement of the field or land and start working. If the working level is not sufficient, it can be brought to the desired level by giving mm level with the +/- keys. The height information of the working area is displayed on the screen. The leveling shovel's excavation amount control system consists of a reference station, GPS receiver, mobile computer, software, hydraulic direction control valve and hydraulic cylinder. The system determines the elevation for leveling using the location information it receives from the reference station and adjusts the angle of the leveling blade to the ground. It adjusts according to the reference value. The geographical position of the reference station was determined precisely and this value was entered into its system. According to this reference location, the positioning corrects the signals it receives from the satellite systems and transmits them to the GPS receiver placed on the leveling shovel (Figure 3).

Figure 3. Reference station and GPS receiver

The GPS System leveling shovel is given in Figure 4, and the sample interfaces related to the tablet and the program loaded on the tablet are given in Figure 5.

Figure 4. Leveling shovel with GPS leveling system

2.1.3. Base station

The GPS leveling system was operated from a reference station that broadcasted a position correction signal. In addition, if the reference station does not work, the system can work by receiving correction signals from TUSAGA Active (CORS-TR) or other systems. A Broadcasting Device with Satellite Ground Level Features of 2 Wat Lora was used as the reference station (Figure 5).

Figure 5. Reference station

2.1.4. Tractor

The tests were carried out with the Case PUMA 170 tractor with a 128 kW engine power (CASEIH, 2025)

2.1.5. Rotating Laser

Laser level detection device TOPCON RL-H3A was used to determine the heights according to the leveling plane on the leveled land (Figure 7). Horizontal accuracy for more reliable leveling in indoor and outdoor finishing works, architecture, construction and civil engineering in agricultural lands, especially for RL-H3A ±1cm precision rotary laser. Higher work efficiency is achieved when using level sensors. Technical specifications are given in Table 3 (TOPCON, 2024).

Figure 7. TOPCON RL-H3A device (TOPCON, 2024)

Table 3. Rotating Laser technical specifications

Model	*TOPCON RL-H3A*
Measuring range (diameter)	Approximately 2 .. 700 m
Horizontal sensitivity	±1.9mm/50 m (±8")
Automatic leveling angle	±3°
Light source	690 nm
Laser class	Class 3A
Rotation speed (min^{-1})	600 (min^{-1})
Protection class	IP56 (Based on the standard IEC 60529)
Battery	BT-49Q (Ni-MH)

2.1.6. Field

The tests were carried out in İpsala, Edirne, Turkiye on April 3, 2024 (Figure 7).

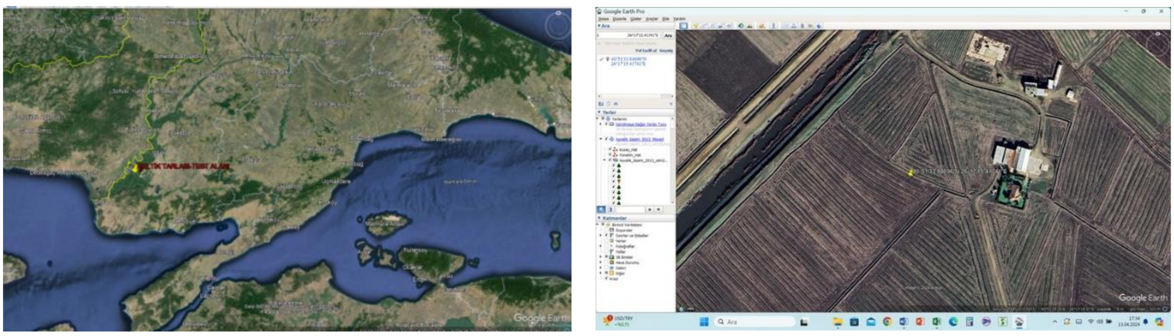

Figure 7. Paddy field, Paşaköy, İpsala (Google Earth, 2024)

2.2. Methods

The GPS leveling system was operated from a reference station that broadcasted a position correction signal. In addition, if the reference station does not work, the system can work by receiving correction signals from TUSAGA Active (CORS-TR) or other systems. Deviations from the reference plane were determined by measurements made from the field leveled according to the reference plane determined by laser. At the same time, the elevation heights of these points are determined from the coordinates determined by GPS. The standard deviation values of the obtained data from the targeted values were calculated with Equation 1 and evaluated by taking into account the tolerances (El-Shikha et al., 2008; Weigiang et al., 2016).

$$SD = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} \quad (1)$$

SD: Standard deviation, (mm)
i: 1…n
n: Total number of the measurements
x_i: Value for i^th measurement $(x_1, x_2, \ldots, x_n)$(mm)
$\bar{x}$: Mean of the measurements (mm)

The measurements were evaluated by calculating the Root Mean Square Error (RMSE) value from Equation 2 (Mohammed, 2012).

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(\bar{x} - x)^2}{n}} \quad (2)$$

$RMSE$: Root Mean Square Errror, (mm)
i: measurmeent number, (1, … , n)
n: Last measurement number
x_i: Value for i^th measurement, (mm)
$\bar{x}$: Mean of the measurements, (mm)

In order to test the levelling system with GPS, 40 measurement points were determined in the field. Geograpical coordinates were determined with GPS and heights were determined by measuring with laser at these 40 points. In evaluating the test results as positive or negative, whether the leveling system provided the conditions for which it was set was evaluated from the data obtained with statistical analyses. The evaluation was made by taking into account the conditions required for the crop to be grown in the field where the leveling was done. In this research; the evaluation was made by taking into account the conditions required for the crop to be grown in the field where the leveling was done. The field where the tests were made was a paddy field and the tolerance allowed here was stated by the farmers as 2 cm.

3. RESULTS

Geographical positions and deviations were measured by GPS and Laser level detection device TOPCON RL-H3A, repspectively. The photographs of the tests were given in Figure 8. Measurement points can be seen on the Figure 9.

Figure 8. Tests of the leveling system with GPS

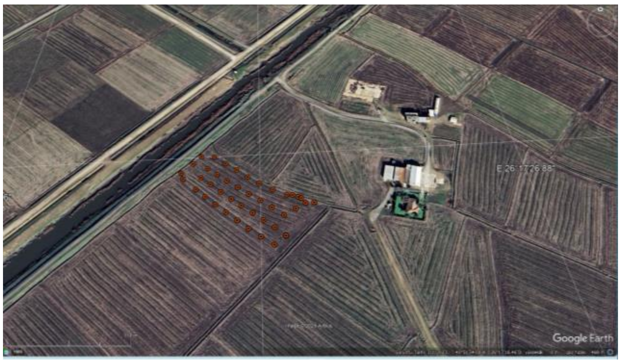

Figure 9. Measurements points

The deviation values of the leveled field surface from the adjusted plane and the coordinates of the measurement points are given in Table 4.

Table 4. Geographical positions neasured by GNSS GPS and Deviations

Points	*Latitude*	*Longitude*	*Elevation (m)*	*Deviation (mm)*
P1	40°51'33.84696"N	26°17'15.41741"E	431.998	0
P1	40°51'33.74759"N	26°17'15.68508"E	433.081	2
P1	40°51'33.46862"N	26°17'16.39897"E	456.766	2
P2	40°51'33.68723"N	26°17'15.81579"E	459.948	4
P3	40°51'33.86907"N	26°17'15.14991"E	433.213	6
P4	40°51'34.14324"N	26°17'14.50964"E	433.176	10
P5	40°51'34.45783"N	26°17'13.86075"E	433.270	10
P6	40°51'34.77825"N	26°17'13.32080"E	433.204	8
P7	40°51'35.14344"N	26°17'12.77787"E	433.211	6
P8	40°51'35.48154"N	26°17'12.23972"E	433.210	6
P9	40°51'35.83993"N	26°17'11.68178"E	433.391	6
P10	40°51'35.88042"N	26°17'11.04112"E	433.293	10
P11	40°51'35.53994"N	26°17'10.64284"E	433.323	6
P12	40°51'35.12143"N	26°17'10.10773"E	433.175	2
P13	40°51'34.83834"N	26°17'10.22716"E	433.161	8
P14	40°51'34.33122"N	26°17'10.88013"E	433.152	6
P15	40°51'33.97734"N	26°17'11.34929"E	433.174	6
P16	40°51'33.61538"N	26°17'11.83432"E	433.184	2
P17	40°51'33.25087"N	26°17'12.34097"E	433.191	6
P18	40°51'32.88597"N	26°17'12.85593"E	433.268	0
P19	40°51'32.52159"N	26°17'13.36563"E	433.228	10
P20	40°51'32.16637"N	26°17'13.92386"E	433.140	6
P21	40°51'31.82374"N	26°17'14.49289"E	432.995	6
P22	40°51'32.15414"N	26°17'15.02504"E	433.030	4
P23	40°51'32.51008"N	26°17'14.54272"E	432.987	10
P24	40°51'32.83923"N	26°17'14.04829"E	433.121	14
P25	40°51'33.16558"N	26°17'13.55315"E	432.973	12

	P26	40°51'33.50399"N	26°17'13.03011"E	433.190	0
	P27	40°51'33.81479"N	26°17'12.56218"E	433.049	4
	P28	40°51'34.15399"N	26°17'12.04819"E	433.231	6
	P29	40°51'34.51387"N	26°17'11.55699"E	433.334	4
	P30	40°51'34.85952"N	26°17'11.07848"E	433.159	2
	P31	40°51'35.28693"N	26°17'11.39027"E	433.287	4
	P32	40°51'34.96935"N	26°17'11.85759"E	433.292	12
	P33	40°51'34.65513"N	26°17'12.33113"E	433.471	8
	P34	40°51'34.31870"N	26°17'12.85289"E	433.486	6
	P35	40°51'33.99594"N	26°17'13.37079"E	433.506	6
	P36	40°51'33.68543"N	26°17'13.91043"E	433.450	6
	P37	40°51'33.35427"N	26°17'14.43225"E	433.197	0
	P38	40°51'33.00176"N	26°17'14.98124"E	433.064	8
	P39	40°51'33.24791"N	26°17'15.53365"E	433.175	0
	P40	40°51'33.46489"N	26°17'16.00782"E	433.136	6
Mean				434.378	5.71
Minimum				431.998	0.00
Maximum				459.948	14.00
SD				5.378	3.48
RMSE					0.262

The leveling height values and tolerance line measured with laser are given in Figure 10.

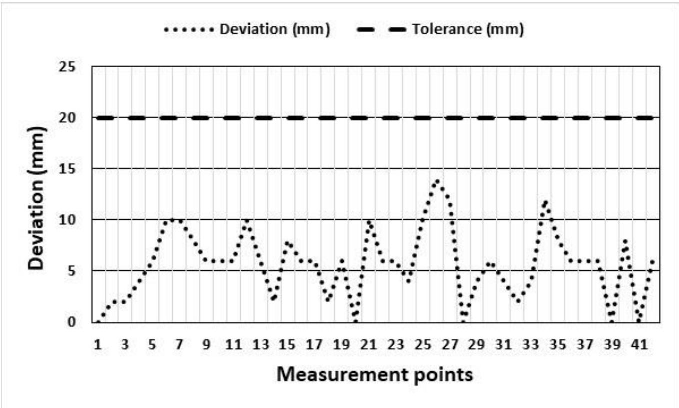

Figure 10. Deviation values from the adjusted leveling plane and tolerance line for paddy

Elevation of hte field changed between 431.998 and 459.948 m. Average elevation was 434.378.

The average value obtained from the measurement points was determined as 5.71 mm, the standard deviation value was calculated as 3.48 mm and the mean square error was calculated as 0.262 mm. The slope tolerance in the pans in rice production was determined as 2 cm in interviews with farmers.

As it can be seen from Figure 5, most of the measured data were below 10 mm. As a result of both the measurement data and the evaluation from the graph and field observations; the GPS leveling system has successfully leveled the land within acceptable limits.

4. CONCLUSION

Levelling system with GPS was tested and evaluated in terms of use with leveling shovels and concluded that it is suitable for agricultural techniques. The GPS levelling system worked successfully in the paddy field within acceptable limits. There is a big potential for GPS to use instead of the levelling system with laser. GNSS GPS system gives opportunity to plannşng field traffic. In addition autonomous systems can also be used in the tractor to decrease driver load and fuel consumption. Future studies may be focused on these topics.

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EXTENDED ABSTRACT

Introduction and Research Questions & Purpose

The purpose of this research was to determine the performance of the GPS levelling system, which uses coordinate data obtained from GPS, which has recently started to be used instead of laser system in levelling shovels widely used in rice farming. In the research, a domestic production system was tested and the obtained data was evaluated statistically.

Methodology

Materials were levelling system with GPS, reference station, rotating laser, leveling showel, tractor, field. The GPS leveling system was operated from a reference station that broadcasted a position correction signal. Deviations from the reference plane were determined by measurements made from the field leveled according to the reference plane determined by laser. At the same time, the elevation heights of these points are determined from the coordinates determined by GPS. The standard deviation values of the obtained data from the targeted values were calculated and evaluated by taking into account the leveling tolerances. The measurements were also evaluated by calculating the Root Mean Square Error (RMSE) value.

Results and Conclusions

Elevation of the field changed between 431.998 and 459.948 m. Average elevation was 434.378. The average value obtained from the measurement points was determined as 5.71 mm, the standard deviation value was calculated as 3.48 mm and the mean square error was calculated as 0.262 mm. The slope tolerance in the pans in rice production was determined as 2 cm in interviews with farmers. Many measurement data were below than 10 mm. As a result of both the measurement data and the evaluation from the graph and field observations; the GPS leveling system has successfully leveled the land within acceptable limits.

The GPS levelling system worked successfully in the paddy field within acceptable limits. There is a big potential for GPS to use instead of the levelling system with laser. GNSS GPS system gives opportunity to planning field traffic. In addition autonomous systems can also be used in the tractor to decrease driver load and fuel consumption. Futur Works may be focused on these topics.

AUTHORS' BIOGRAPHY

Bahattin AKDEMİR

Bahattin Akdemir works as a faculty member in the Department of Biosystems Engineering, Agricultural Machinery Systems Division, at Namık Kemal University in Tekirdağ. He conducts research on agricultural machinery, tractors, and smart farming/precision.

İletişim bakdemir@nku.edu.tr

ORCID Adresi https://orcid.org/0000-0001-9872-1823