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Effect of Center Pivot System Lateral Configuration on Water Application Uniformity in an Arid Area

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ABSTRACT

System evaluations were performed on 48 center pivots in different parts of Saudi Arabia. These systems, located on different farms in four different regions of the country, namely: Riyadh, Jouf, Qassim and Eastern regions, were evaluated to study the effect of lateral configuration on water application uniformity as regards the original *vs.* modified laterals. Lateral configuration modifications have been made by the local farmers through a chang of the position of the lateral and spray nozzles from the original design. Depths of water distribution along the lateral, Coefficient of uniformity (Cu) and Distribution uniformity of the low quarter (Du) were determined and compared for the original and modified laterals under field conditions. The average values of *Cu* for original systems ranged between 71.81 and 89.46% with an overall average of 82.69%, whereas the average values of *Cu* for modified systems rangingbetween 61.35 and 84.33% with an overall average of 78.05%. Also, the values of Du ranged between 54.14 and 81.81% with an overallaverage of 73.24% for the original systems, while these values for the modified systems ranging between 31.45 and 77.07% with an overall average of 66.87%. The results finally indicated that the values of uniformity for original *vs*. modified laterals were significantly different indicating that there existed a noticble adverse effect of center pivot lateral configuration on the uniformity of water application.

Keywords: Application uniformity, Center pivot, Lateral configuration, Sprinkler irrigation.

INTRODUCTION

A center pivot basically consists of a pipeline (lateral) mounted on motorized structures (towers) equipped with wheels. The system rotates around a "pivot" point located in the center of the field. Sprinkler outlets are installed on the top of the pipe line supported by steel trusses between adjacent tower structures. The towers are usually 30 to 60 m apart with each tower equipped with a 1 hp motor and sitting on two large wheels.

Center pivot irrigation systems comprise approximately two thirds of all the irrigation systems, in about 75% of the total irrigated area, in the Kingdom of Saudi Arabia (KSA). These sprinkler irrigation systems have allowed agricultural development of "marginal" lands unsuitable for surface irrigation in many areas across the KSA, mostly suffering from light sandy soils of large variations in topography within the same field.

These very adaptable water application systems have experienced tremendous growth around the world in recent years due to: (1) their potential for highly efficient and uniform water application; (2) high degree of automation requiring less labor than most other irrigation methods; (3) large areal coverage; and (4) their ability to economically apply water and water soluble nutrients over a wide range of soil, crop and topographic conditions. For these reasons, center pivot irrigation in the KSA has increased rapidly since 1982. There were about 20,028 center pivots in the country in

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1995, mainly imported to irrigate wheat crops (Al-Ghobari and Mohammed, 1995).

During the last thirty years, large areas of desert land in Saudi Arabia have been converted into productive irrigated farms. The irrigated area has increased from about 0.5 million ha in 1975 to about 1.62 million hectares in 1992, and then reduced to about 1.1 million hectares in 2007 (MFNE, 2008). This final rapid increase in the irrigated land has resulted in a substantial increase in demand for irrigation water leading to unbalance between the available water resources *vs.* demands. Water consumption in 1992 exceeded 85% of the national water use, with the non-renewable groundwater resources being the source of about 92% of the irrigation water (MFNE, 2008). The increase in agricultural land was because the government supported and encouraged farmers to contribute to securing the Kingdom's food supply. As a result, the number of center pivot systems increased rapidly during the last three decades.

The use of center pivot systems to irrigate vast farm lands in the country with water of different qualities caused excessive corrosion to the lateral pipes. This frequent problem led farmers to replace the high cost steel laterals with polyethylene pipes to reduce the corrosion problem. The plastic laterals were positioned below the original laterals and above the soil surface at about 1.5-2.0 m while equipped with short drop tubes. This replacement and configuration of system of laterals was initioated by farmers with advise from their own technicians using their own experience and with no reference to either the center pivot distribution dealers or the center pivot and sprinkler package designers which is based and stablished upon maintaining a predetermined pressure at each sprinkler in the system. Also, there was no field evaluation made of these center pivots following the modification introduced to judge the performance and overall proper water distribution. The replacement of the galvanized steel pipes every 3-5 years is very common among center pivot owners in the country, depending on salinity state of the irrigation water.

There is a dire need for irrigation system evaluation because these systems may not have been well designed and properly functioning. The type of study is seriously needed to provide direction to management in deciding whether to continue the existing practices or to attempt for their correction and improvement. Improved management of irrigation water on the farm can conserve water, labor, and soil and can also lead to an increase in the yields of crops. Center pivot systems should be evaluated for an appraisal of their efficiency and performance during operation to be compared with the genuinely designed and installed center pivot systems located on the same farm or on any other nearby farm. The objective of the present study was to evaluate the center pivot systems under field conditions, and to determine the effect of change in lateral configuration on water application uniformity. A comparison was also made among the modified center pivot systems under local operating conditions.

For an attainment of sustainable water use, the resources have to be utilized in such a manner as to protect and conserve the available water reserves (Sezen and Yazar, 2006). In irrigated agriculture, this will have to be achieved through effective management of water use. Therefore, irrigation systems will have to handle and use water in their most efficient ways possible to prevent unnecessary losses (Bur *et al.,* 1997; Dukes and Perry, 2006). To achieve this, the uniformity coefficient with which the irrigation systems apply water will have to be high. The uniformity coefficient of a sprinkler irrigation system directly affects the system's application efficiency and crop yield as well (Li and Rao, 2000; Dechmi *et al.,* 2003; El-Ansary *et al.,* 2003). Poor distribution uniformity reduces yields due to water stress. It also increases financial and environmental costs (Clemmens and Solomon, 1997).

Proper irrigation uniformity in center pivot systems is important since it has both

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economic and environmental implications. Harrison and Perry (2007) classified pivot coefficient uniformity (CU) values as excellent: > 90%, good: 85 to 90%, fair: 80 to 85%, and poor: < 80%. Furthermore, the USDA-NRCS established that chemigation should only be used on center pivot systems benefiting from CU values > 85% (USDA-NRCS, 2003).

Conventionally, center pivot irrigation systems are evaluated by placing a transect of catch cans, uniformly spaced and radially outwards from the pivot point along the lateral. As the installation travels across the transect, water is caught in the cans, then the system performance is evaluated using the volume of water caught in the cans as data. The uniformity of water application could be influenced by many factors, some of the main ones being improper sprinkler nozzling and spacing, wear of sprinklers and pipes, variation in pressure distribution along the lateral as well as wind speed (Keller and Bliesner, 1990; Al-Ghobari, 1992, 1996, 2010). The center pivot uniformity along the travel path is assumed to be high, because the continuously moving sprinkler system integrates the sprinkler pattern along the travel path (Jensen, 1981).

Considerable research by many investigators has been conducted in the field to evaluate the performance of the center pivot sprinkler irrigation systems (Heermann and Hein, 1968; Marriam and Keller, 1978; Ring and Heerman; 1978; James and Blair, 1984; Von Bemuth and Gilley, 1985; Hanson and Wallender, 1986; Jonhnson *et al.,* 1987; Clemmens and Solomon, 1997; Tarjuelo *et al.,* 1999; Al-Ghobari, 1994; Ring and Heerman; 2001; Rogers *et al.,* 2009).

MATERIALS AND METHODS

Forty eight low-pressure center pivot sprinkler irrigation systems operating on fields located at four different regions of Saudi Arabia, namely: Riyadh and Qassim in the center, Jouf in the north and some in the eastern region were made use of throughout the study. The distribution of water application depths recorded from spray nozzles along the lateral was assessed.

$$Cu = 100 \times \left[1.0 - \left(\frac{\sum_{\eta} S_s \left| D_s - \frac{\sum_{\eta} D_s S_s}{\sum_{\eta} S_s} \right|}{\sum_{\eta} D_s S_s} \right) \right] \quad (1)$$

The following formula was employed to calculate *Cu* was:

Where: *Cu* = Heermann and Hein uniformity coefficient; *D*= Total depth of application at distance *S* from the pivot point; S= Distance from the pivot point to the collector; = subscript Denoting a point at a distance *S*, η= Number of water catching containers.

Another index used to assess the uniformity of applied water in the irrigated area was the Distribution uniformity (Du) in the low quarter given as:

$$Du = \frac{dw}{Dw} \times 100 \quad (2)$$

Where: dw = Average weighted low quarter depth and Dw = average weighted depth applied.

Du is also a useful indicator of the extent of water distributional problems. A low *Du* value indicates losses due to deep percolation being excessive.

Field Evaluation

System testing was carried during 2008-2009. The operating age of the systems ranged from 5 to 20 years, and the number of towers varied from 6 to 8. All farms included in the evaluation belonged either to farmers or to agricultural companies. Some of the farms were equipped with center pivot systems of both original *vs.* the ones with modified laterals, but the majority of the

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farms were equipped only with center pivot systems of the modified laterals.

The original pivot lateral (Figure 1-a) within these center pivot systems was built of galvanized steel pipe (Table 1), while the center pivot systems with modified laterals (Figure 1-b) carried a polyethylene pipe of the same diameter all through and positioned below the original lateral. The height of the modified lateral was close to the soil surface as compared with the original lateral with the new height from soil surface ranging between 1.5 and 2.0 m, and the lengths of the drop tubes connected to the modified lateral ranging from 0.5 to 1.0 m. none of the sprinklers, installed along the modified lateral were equipped with pressure regulators.

Field evaluations were conducted adopting the methodology of Merriam and Keller (1978) and ASABE Standard, S436.1 (2007). Wind speeds ranged from 1.5 to 6.3 m s^{-1}, the air temperature from 17 to 30°C, and while the relative humidity varying between 28 and 57 %. Two rows of catch cans were used in each system to measure the uniformity of water distribution in the radial direction as shown in Figure 2. The catch can spacing was chosen 5 m with the first can at 11.6 m from the pivot point (Merriam and Keller, 1978). Catch cans of 16 cm inside diameters and 15 cm heights were made use of. The catch cans were placed along a line extending radially from the pivot point. The two lines were sufficiently distanced apart from the pipeline to allow for the system to allow for the testing conditions. The operating speed of

(a) Original lateral (b) Modified lateral

Figure 1. Two types of center pivot systems employed in the study with (a) original and (b) modified laterals.

Table 1. Some specifications of most of the original system laterals employed in the study.

Item	Specification
Pivot height	4.3 m
Pipe diameter	Span 1-6=168.22 mm and Span 7-8=141.22 mm
Tower height	3.8 m
Span length	52 m
Nozzle type	Senninger (360/cv-m)
Nozzle spacing	2.54 m
Pressure regulator model	PMR – 15

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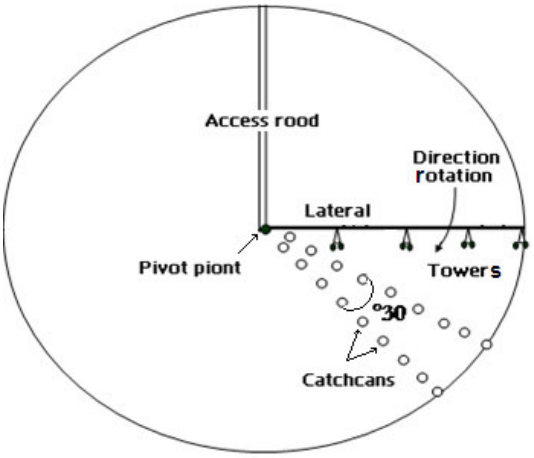

Figure 2. Field layout and schematic diagram demonstrating the distribution of catch cans.

the systems was set constant and at 50%. There was no end-gun sprinkler installed on any system tested. Field tests were carried out on either bare soil or soil with early-staged crop growth. All tests were carried out under normal field conditions in the early morning with the water collected in the catch cans measured making use of graduated cylinders. The measurements were carried out at such a quick time as possible to have least evaporation losses from the collectors. The source of irrigation water in the study areas was groundwater pumped from wells's deep aquifers. The salinity of irrigation water was estimated from the electrical conductivity (EC_{wi}) measured for each well. The average values of EC_{wi} for the four regions ranged from 0.46 to 6.55 dS m^{-1}.

RESULTS AND DISCUSSION

Water application uniformity is a measure of how evenly water is spread over the soil surface during irrigation under different field operating conditions. Water distribution profiles along the laterals of the tested center pivot systems are shown in Figures 3 (a and b) and 4 (a and b) for original and modified laterals, respectively. The profiles depict water depths caught in each can along the lateral for each of the 32 center pivot systems. The figures show that substantial areas of the center pivot systems were receiving less than the average amount of water applied and there was substantial variation in depth of water applied along the lateral from one system to another, especially for center pivot systems with modified laterals. Average depths and average low quarter depths of application for each system were determined and displyed (Figures 3 and 4). Average depths and the low quarter average depths of application for 24 center pivot systems equipped with original laterals ranged from 24.33 to 4.31 mm, and from 17.42 to 2.33 mm respectively, whereas, the average depths and the low quarter average depths of application for the 24 modified systems (Figure 4) ranged from 13.23 to 5.23 mm and from 9.36 to 3.59 mm respectively. It can be seen that both depth values for the original systems were higher than those for modified systems. This indicates that more water was applied through the original center pivot systems to the irrigated areas as compared with the center pivot systems with modified laterals and when at the same travel speed. The lower depth values were attributed to lateral configurations changes made by farmers, bringing about pressure variations, improper nozzling, inaccurate water patterns and as well leakage along the laterals.

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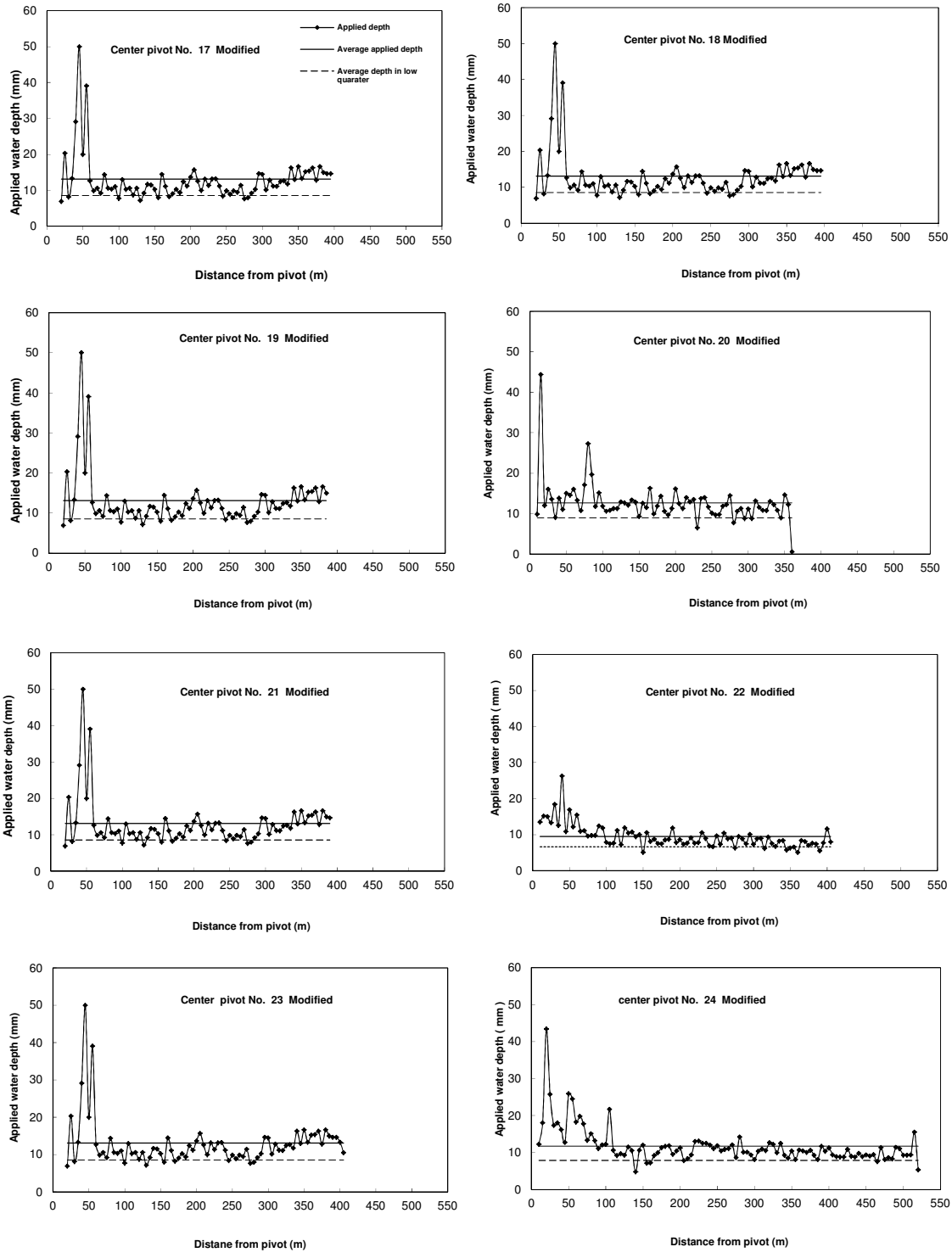

(a)

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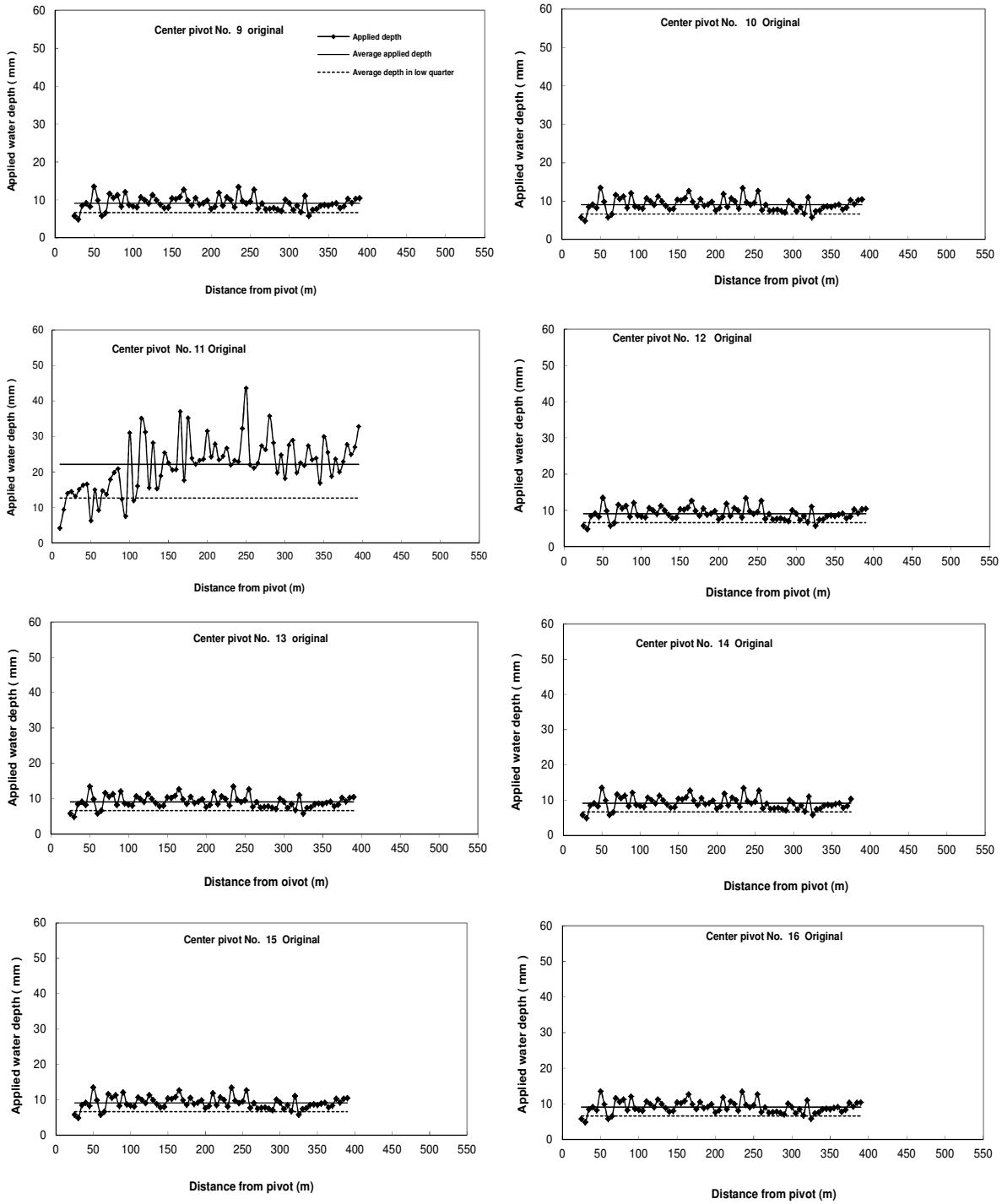

(b)

Figure 3. Water distribution patterns in radial direction with the average depths and the average low quarter depths of application recorded from center pivot systems with original laterals.

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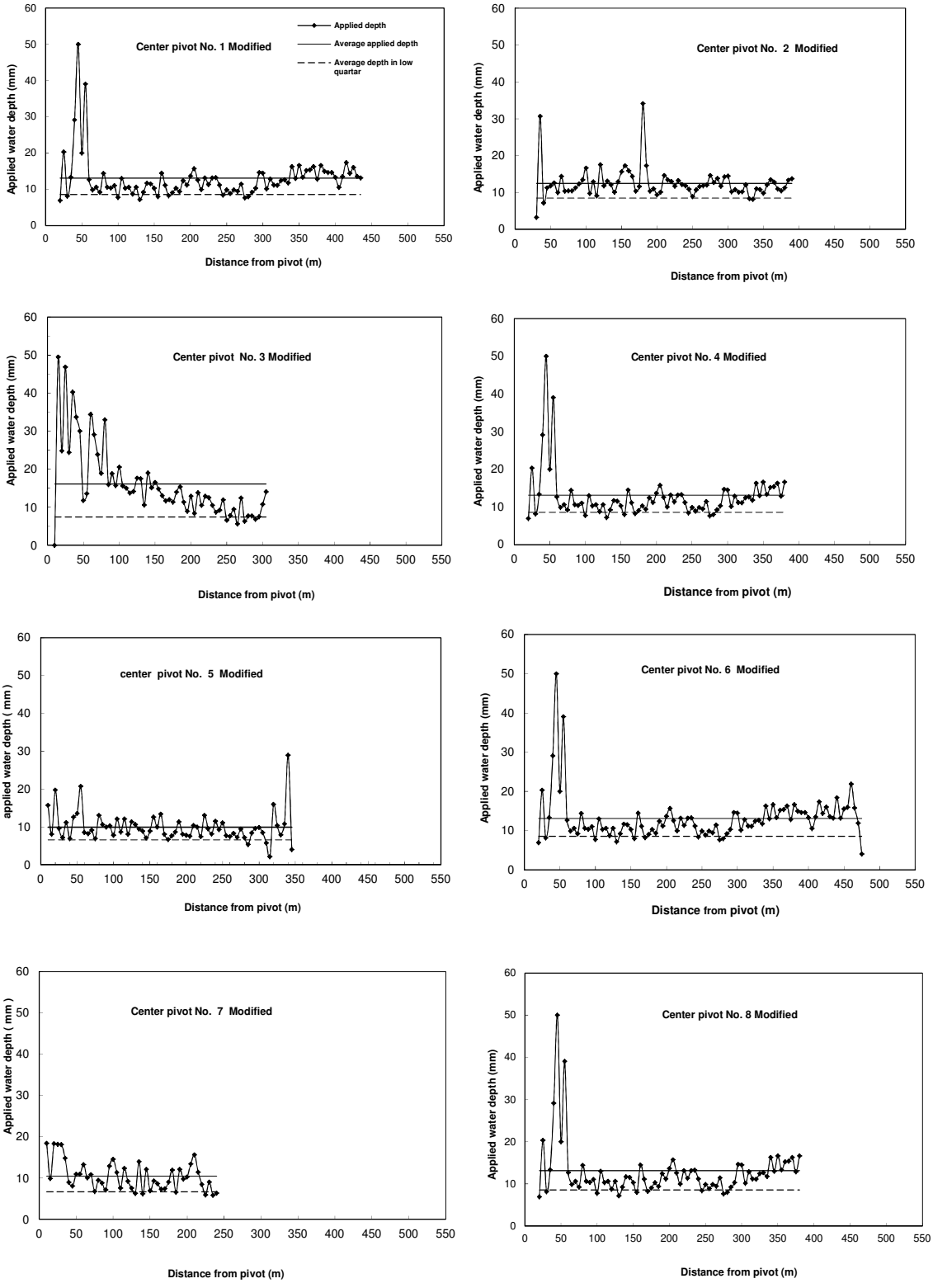

(a)

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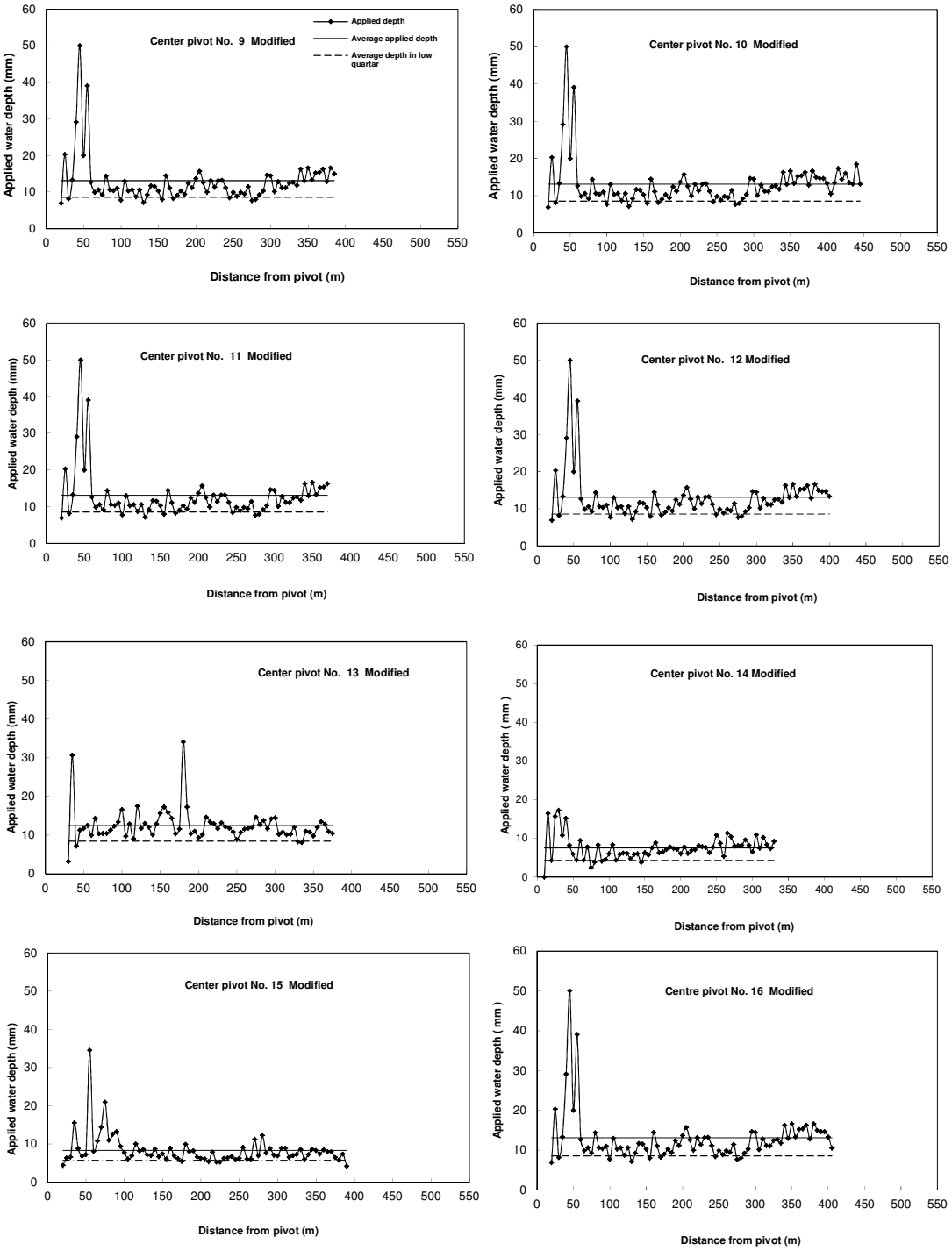

(b)

Figure 4. Water distribution patterns in radial direction with the average depths and the average low quarter depths of application recorded from center pivot systems with modified laterals.

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To compare how well the center pivot irrigation systems applied water to the irrigated areas and to determine whether each system was operating at an acceptable uniformity, performance index values were determined and compared. This was done by calculating the values of *Cu* and *Du,* employing Equations (1) and (2) for the 48 center pivot systems. A comparison of the performance index values and the uniformity differences made between the original *vs.* the modified systems are shown in Figure 5. It can be seen that the index values were lower for center pivot systems with modified laterals as compared with the center pivot systems equipped with the original laterals. Also, Figure 5 shows the difference in values between *Cu* for original and modified laterals, the average values of *Cu* for original systems ranged between 71.81 and 89.46% with an average of 82.69%, whereas the average values of *Cu* for modified systems ranged between 61.35 and 84.33% with an overall average of 78.05%. Also, the values of *Du* (Figure 5) ranged between 54.14 and 81.81% with an overall average of 73.24% for the original systems. The values of *Du* for the modified systems ranged between 31.45 and 77.07% with an overall average of 66.87%. This also, indicates that original center pivot systems performed more accurately and applied water more uniformly to the soil surface as compared with the modified systems.

Taking 80 and 67% as acceptable performance levels for Cu and Du, respectively, (Merriam and Keller, 1978), *Cu* and *Du* values for most of the modified systems were below acceptable levels. But for the majority of original center pivot systems, irrigation water was distributed more uniformly and most values of *Cu* and *Du* well above the 80 and 67% levels. Thus, it can be said that the performance of the original systems was better than the performance of the modified systems, and water applied more uniformly. Poor distribution uniformity and wide variations in depths of water applied along the laterals are obvious in the modified systems. This would adversely affect crop growth and yield of field crops irrigated through these center pivot systems.

Non-uniformity of the modified systems

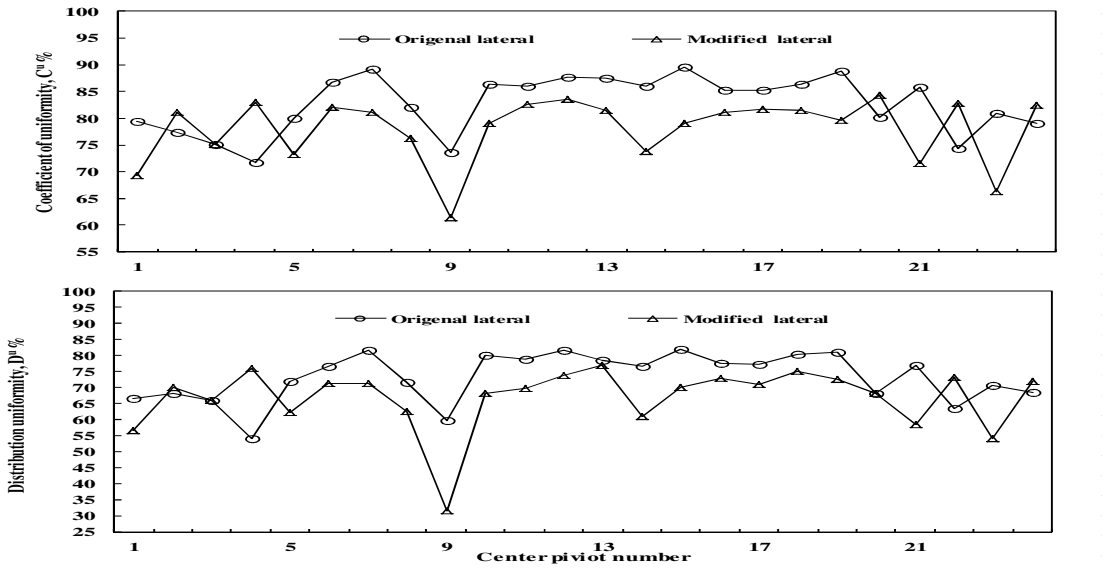

Figure 5. A comparison between values of coefficient of uniformity (Cu) and distribution uniformity (Du) for 48 of the original *vs.* modified center pivot systems.

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were caused by an improper location of the laterals and their variations in height from the soil surface (Figure 1-b) and subsequent variations in the nozzles' pressure along the lateral. This caused the sprinkler discharge and application depth patterns along the modified laterals to be different from those in the laterals of original installments.

Analysis of Variance (ANOVA) was performed on values of *Cu* and *Du* for the center pivot systems with original *vs.* modified laterals using one-way analysis of *t*-test. The performance indexes for the two systems were compared using Least Significant Difference (LSD) at 5 and 1% probability levels. Statistical analysis revealed that there existed a significant difference between *Cu* values for center pivot systems of the original *vs.* modified laterals at either level of 1 and 5%. This means that the lateral configuration had a highly significant influence on the performance indexes of these center pivot systems, and therefore the change of lateral position and sprinkler packages along the lateral have brought about poor performances. This will significantly influence the irrigation water distribution and the center pivot system's performance, leading to increase in water losses accompanied by a decrease in crop yield.

CONCLUSIONS

The present study was conducted to investigate the effects of center pivot lateral configuration on the uniformity of water distribution along the laterals of 48 center pivot sprinkler irrigation systems. The results showed that water distribution along the modified lateral (polyethylene pipe) was affected by the change of lateral configuration in these systems with the performance indexes amounting to their low values, the majority of which were below the generally acceptable levels as compared with the index values of center pivot systems equipped with the original laterals. Statistical analysis revealed that the values of uniformity for original and modified laterals were significantly different. It was confirmed that systems with modified laterals were delivering water with low uniformity along with non-uniform water depth distribution along the newly set lateral in comparison with the originally designed. The low uniformity of the modified systems was due to the most commonly observed problems of improper nozzling, worn nozzles and leakage especially at some drop tubes' connection with the lateral due mainly to a lack of a proper system of maintenance.

The change of lateral position and replacing the original lateral by polyethylene plastic pipes instead of the original galvanized pipes in center pivot systems is a common practice among farmers in the country. This was mainly done to reduce the corrosion problem occurring with galvanized steel pipes of the original systems. This study is expected to draw the attention of sprinkler irrigation system users and of farm managers to the importance of the original and authentic set up of the laterals. An ignorance of the calculated lateral configuration based upon maintenance of a predetermined pressure at each sprinkler in the system (along the lateral) will cause significant irregularities in the water distribution along the laterals.

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REFERENCES

1. l-Ghobari, H. M. and Mohammed, F. S. 1995. Survey Study about the Crust Problem in Center Pivot Irrigation Pipes in the Kingdom of Saudi Arabia. Agricultural Ressearch Center; KSU, 54 PP.
2. Al-Ghobari, H. M. 1994. A Field Study for Evaluation of Center Pivot System

[DOR: 20.1001.1.16807073.2014.16.3.12.0]

Performance under Arid Regions. *Bull. Fac. Agri. Univ. Cairo,* **45:** 765-784.
3. Al-Ghobari, H. M. 1992. Losses from Low-pressure Center-pivot Irrigation System in a Desert Climate as Affected by Nozzle Height. *Agriculture Water Manag.,*, **21:** 23–32.
4. Al-Ghobari, H. M. 1996. The Effect of Travel Speed on Spray Losses from Center Pivot Systems. *J. King Saud Univ. Sci.,* **8:** 111-123.
5. Al-Ghobari, H. M. 2010. The Performance of the Center Pivot Irrigation Systems under Riyadh Region Conditions in Saudi Arabia. *Journal of the Saudi Society of Agricultural Sciences,* **9(2):** 55-68
6. ASABE, Standard, S436.1. 2007. Test Procedure for Determining the Uniformity of Water Distribution of Center Pivot and Lateral Move Irrigation Machines Equipped with Spray or Sprinkler Nozzles. St. Joseph, Mich, USA.
7. Burt, C. M., CLemmens, V., Strelkoff, T. S., Solomon, K. H., Bliesner, R. D., Hardy, T. A., Howell, H. and Eisenhauer, D. E. 1997. Irrigation Performance Measures: Efficiency and Uniformity. *J. Irrig. Drain. Eng.,* **123:** 423-442.
8. Clemmens, A. J. and Solomon, K. H. 1997. Estimation of Global Irrigation Distribution Uniformity. *J. Irrig. Drain. Eng.,* **123:** 454-461.
9. Dechmi, F., Playan, E., Faci, J. and Tejero, M. 2003. Analysis of an Irrigation District in Northeastern Spain. I: Characterization and Water Use Assessment. *Agriculture Water Manag.,* **61:** 75–92.
10. Dukes, M. D. and Perry, C. 2006. Uniformity Testing of Variable-rate Center Pivot Irrigation Control Systems. *Precision Agriculture,* **7:** 205 - 218.
11. El-Ansary, M. Y., El-Gindy, A. M., Awad, M. A. and Wasif, E. 2003. Evaluation of the Alternate Sets Management of Sprinkler Irrigation. *The 11th Annual Conference of Misr Society of Agricultural Engineering,* 15-16 October, Egypt, **20:** 236 - 250.
12. Hanson, B. R. and Wallender, W. W. 1986. Bidirectional Uniformity of Water Applied by Continuous Move Sprinkler Machines. *Trans. ASAE,* **29:** 1047-1053.
13. Harrison, K. and Perry, C. 2007. Evaluating and Interpreting Application Uniformity of Center Pivot Irrigation Systems. Circular 911, University of Georgia, Athens, GA.
14. Heermann, D. F. and Hein, P. R. 1968. Performance Characteristics of Self-propelled Center Pivot Sprinkler Irrigation Systems. *Trans. ASAE,* **11:** 11-15.
15. James, L. G. and Blair, S. K. 1984. Performance of Low Pressure Center Pivot Systems. *Trans. ASAE,* **27:** 1753-1762.
16. Jensen, M. E. 1981. *Design and Operation of Farm Irrigation System*. The American Society of Agric. Engineers, St. Joseph, Mich., PP. 583-618.
17. Johnson, G. C., Rochester, E. W., Hatch, L. U., Curtis, L. M. and Yoo, K. H. 1987. Analysis of Center Pivot Irrigation Systems Operating in a Humid-area Environment. *Trans. ASAE,* **30:** 1720–1725.
18. Keller, J. and Bliesner, R. D. 1990. *Sprinkler and Trickle Irrigation*. Van Nostrand, Reinhold, New York, 643 PP.
19. Li, J. and Rao, M. 2000. Sprinkler Water Distributions as Affected by Winter Wheat Canopy. *Irrig. Sci.,* **20**: 29-35.
20. Merriam, J. L. and Keller, J. 1978. Farm Irrigation System Evaluation: A Guide for Management. Utah State University, Logan, Utah.
21. Ministry of Finance and National Economy (MFNE). 2008. *Statistical Yearbook*. Central Department of Statistics, MFNE, Riyadh, Saudi Arabia.
22. Ring, L. and Heerman, D. F. 1978. Determining Center-pivot Sprinkler Uniformities: Paper No. 78: 2001. *ASABE*, St. Joseph, Mich.
23. Ring, L. and Heerman, D, F. 2001. Determining Center-pivot Sprinkler Uniformities: ASAE Paper No. 78. *ASAE,* St. Joseph, MI 49085.
24. Rogers, D. H., Alam, M., Shaw, L. K. and Clark, G. A. 2009. Impact of Collector Size and Spacing on Center Pivot Uniformity Evaluation: Paper Number: 09-6522. *ASABE Annual International Meeting*.
25. Seginer, I., Kanetsu, D., Nir, D. and VonBernuth, R. D. 1992. Indoor Measurements of Single-radius Sprinkler Patterns. *Trans. ASAE,* **35:** 523-533.
26. Sezen, S. M. and Yazar, A. 2006. Wheat Yield Response to Line-source Sprinkler Irrigation in the Arid Southeast Anatolia Region of Turkey. *Agriculture Water Manag.,* **81:** 59–76.
27. Tarjuelo, J. M., Montero, J., Honrubia, F. T., Ortiz, J. J. and Ortega, J. F. 1999. Analysis of Uniformity of Sprinkler Irrigation in a

[DOR: 20.1001.1.16807073.2014.16.3.12.0]

Semi-arid Area. *Agricultural Water Manag., USA,* **40:** 315 - 331.
28. USDA/NRCS. 2003. *Conservation Practice Standard: Irrigation System, Sprinkler: CODE 442*. USDA Natural Resource Conservation Service, Washington, DC.
29. Von Bemuth, R. D. and Gilley, J. R.1985. Evaluation of Center Pivot Application Packages Considering Droplet Induced Infiltration Reduction. *Trans. ASAE,* **28:** 1940-1946.

تاثیر انواع مختلف لوله های آبده (لترال) در سیستم های سنتر پیوت بر یکنواختی پخش آب در یک منطقه خشک

ح. م. الغباری

چکیده

در این تحقیق ۴۸ سامانه سنتر پیوت که در مزارع بخش‌های مختلف عربستان سعودی، از قبیل ریاض، قصیم وبخش شرقی قرار دارند، برای مطالعه و ارزیابی لاترال‌های اصلی و اصلاح شده بر یکنواختی توزیع آب، در نظر گرفته شده‌اند. زارعین محلی علاوه بر تغییر نازل‌های پاشش اصلی، موقعیت لاترال‌ها را نیز نسب به طرح اولیه تغییر داده اند. پارامترهایی از قبیل عمق آب توزیع یافته در طول لاترال، ضریب یکنواختی، CU، و توزیع یکنواختی ربع پایین (DU)، برای لاترال‌های اصلی و تغییر یافته تعیین شدند. دامنه میانگین ضریب یکنواختی برای سامانه‌های اصلی بین ۷۱.۸–۸۹.۵ درصد با متوسط ۸۲.۶٪ در حالی که این مقادیر برای سامانه‌های تغییر یافته به ترتیب۸۴.۳–۶۱.۳ درصد و ۷۸.۰٪ بوده اند. همچنین مقادیر DU برای سامانه اصلی در دامنه ۵۴.۱–۸۱.۸ درصد با میانگین۷۳.۲٪ قرار داشت، اما این مقادیر برای سامانه تغییر یافته به ترتیب۳۱.۴–۷۷.۰ درصد و میانگین ۶۶.۸٪ به‌دست آمده است. ارزیابی‌ها نشان داد که تغییر ایجاد شده توسط زاعین محلی بر مقادیر توزیع اثر جدی داشته است.

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