

8. Spatial distribution of soil water content in potato horizontal-ridge profile under various ridge dimensions

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Spatial distribution of soil water content in potato horizontal-ridge profile under various ridge dimensions

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Abstract. Vertical (slopping)-ridge is generally applied to cultivate potato crop in tropical highland area with intensive use of non-organic fertilizer, by which the soil erosion as well as environmental degradation might be significantly accelerated. On the other hand, horizontal (contour)-ridge has been very effective to reduce the soil erosion in potato cropping field, but yet slightly ineffective to support the optimal crop production, due to the waterlogging in the ridge profile. Dimension of the horizontal-ridge is expected to affect water distribution as well as the waterlogged condition, on which a specific study need to be focused, in order to develop an appropriate drainage system on the ridge. This study was aimed to characterize the spatial distribution of soil water in the horizontal-ridge profile under various ridge dimensions. Totally 9-potato-plots of 300 x 300 cm² with 5% slope were prepared in Serang village, Purbalingga with various dimensions and replications of the horizontal ridges: 30 x 30 x 30 cm³ (G30), 30 x 40 x 30 cm³ (G40), and 30 x 50 x 30 cm³ (G50). Of each plot, the dielectrically (volumetric)-water content of the horizontal-ridge soil within the grid of 80 x 80 cm² at the depth of 5, 10, and 20 cm were measured every months using EC5 moisture sensors and EM50 data logger, and then averaged. Based on the given grid, the data were plotted in contour pattern and were then analysed using semivariogram (Gstat and GnuPlot) to characterize the spatial distribution and variability, respectively. The results showed that the spatial distribution of dielectrically (volumetric)-water contents tended to be inter-correlated within each ridge dimension, and the data were increased with soil depth and ridge dimension increment. Accordingly, the data were spatially-correlated with *sill* (C , *semivariance*) ranged from 0.00084 – 0.00429 cm³ cm⁻³ and *range of influence* (a) ranged from 0.624 – 2.809 m, in which the G50 had most representative and stable trend of the spatial variability (C and a values) among others.

Keywords: Horizontal ridge; potato crop; ridge dimension; soil water content; spatial variability



1. Introduction

Potato is a horticultural product having potential market sell. The product is now becoming the second highest export demand of 5.5 million ton per year or equivalent to USD of 4.23 million [1]. In other hand, the domestic production is limited still, thus some efforts is required to increase the production sustainably, for instance, by applying the appropriate cultivation methods.

In tropical area, potato is generally cultivated in highland areas under slopping-land and -ridge to meet suitable soil physical as well as aeration condition for the good production [2]. The method, however, causes severe soil erosion that accelerate land degradation either on site or in surrounding environments [3,17,23]. Therefore, introducing an alternative method is important to minimize the degradation and to increase the production simultaneously.

A horizontal (contour)-ridge has been introduced and implemented during a last decades. For instance, [3] reported that applying the horizontal ridge in highland potato cultivation might reduce the run-off and soil loss (soil erosion) by 17-34% and 67-73%, respectively, as compared to the vertical-ridge, depend on slopes and cultivation seasons. However, the production tended to reduce by 12-23% in rainy season [2,3]. This was expected due to waterlogging within the ridge profile [4].

Based on the problems above, understanding the spatial distribution of soil water within the horizontal-ridge profile is essential [3,4], as the initial step to determine an appropriate drainage technique as well as to reduce the waterlogged in the ridge-profile. Furthermore, the land management practices including tillage, mulching, and ridging or mounding tends to affect water content and redistribution in soil [5,6,7,18,21]. Unfortunately, the research on this issue especially the relationship between ridging practice and soil-physical properties distribution has been rarely documented.

This study was aimed to characterize the spatial distribution of soil-water in the horizontal-ridge profile under various ridge dimensions. The study might clarify the spatial distribution pattern of soil water in the ridge profile, on which the drainage technique can be then appropriately implemented.

2. Materials and method

2.1. Experimental site

The research was conducted on a potato cropping plot located at Serang village, Purbalingga (7°14'31'' S, 109°16'50''E) with a typical soil of Andisol (Table 1). As shown in Figure 1, the plot was divided into 9 sub-plots (3 m x 3 m large) having 4 horizontal-ridges each (as replication, 75 cm ridge interval) under various ridge dimensions (widths): 30 x 30 x 30 cm (G30), 30 x 40 x 30 cm (G40), and 30 x 50 x 30 cm (G50) and 5% field slope. On these sub-plots, organic fertilizers: chicken manure and Petroganik (a local commercial product: 12.5% C-organic, 10-25 C/N ratio) were applied with the rate of 10 and 20 ton ha⁻¹, respectively in order to meet equivalent rate of NPK with those of the inorganic fertilizer usually used. At the horizontal-ridges of each sub-plot, potato crop was then sowed with cropping interval of 40 cm. Furthermore, plastic sheet (80 cm in height) was vertically installed along each sub-plot edges, and sediment collector was put at each sub-plot lower side.

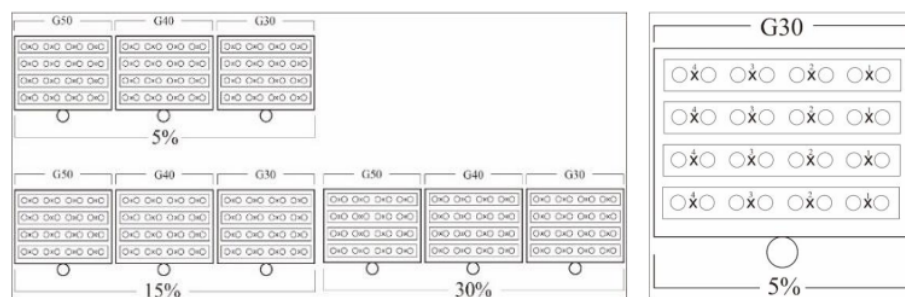


Figure 1. Experimental plots and design/treatments (left side), and samples points (right side).

Table 1. Physical and chemical properties of Serang's Andisol soil

Parameter	Dimension	Value
Texture		Loam
Sand	g g ⁻¹	37.44
Silt	g g ⁻¹	48.18
Clay	g g ⁻¹	14.38
Field capacity	%	44.07
Permanent wilting point	%	19.83
C-organic	%	5.60
pH		4.96
Total-N (Available-N)	% (ppm)	0.52 (57.16)
Total-P (Available-P)	% (ppm)	0.49 (0.61)

(Source: [4])

2.2. Sample collection and measurement

Throughout a cultivation period (3 months), the (dielectrically)-volumetric water content (θ) of soil at 5, 10, and 20 cm depth were measured on the horizontal ridges of each sub-plot (nearby potato crops, following the grid/rectangle of 75 cm x 75 cm) every month using EC5 moisture sensor, of which the data were recorded by EM50 data logger (Decagon Inc.) (Figure 1). The disturbed soil samples were also taken from the similar locations at the same depth and time as the undisturbed soil samples collection. The samples were analyzed to determine basic physical properties of the soil (Tabel 1).

2.3. Data analysis

Of each sub-plot, the (dielectrically)-volumetric water content (θ) of soil within 3 months at 3 depths sampling were calculated based on [8]'s method and then averaged to meet more representative sub-plot data. Following the given grid/rectangle form, the data were then plotted in contour pattern to clarify the spatial distribution.

The spatial variability of the dielectrically (volumetric) water contents were analysed using semivariogram ($\gamma(h)$) (Spherical model, Gstat and GNUplot) as shown in Equation 1 [9] and 2 [10]. Furthermore, the missing data were equipped using Kriging interpolation (in Surfer 16).

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [z(x_i) - z(x_i + h)]^2 \quad (1)$$

where, $N(h)$ is the number of sample pairs separated by a distance h , $z(x_i)$ is the measured sample value at point x_i , and $z(x_i + h)$ is the measured sample value at a distance h from x_i .

$$\gamma(h) = \begin{cases} C_o + C \left[\frac{3h}{2a} - \frac{h^3}{2a^3} \right]; & 0 \leq h \leq a \\ C_o + C; & h \geq a \end{cases} \quad (2)$$

where, h is the distance of sample pairs, C_o is the nugget effect, $C_o + C$ is sill, and a is the range of influence (for spherical model, effective distance (a^*) = $2/3a$).

3. Results and discussion

3.1. Spatial distribution of the volumetric water content of soil

The spatial distribution of the volumetric water content (θ) of soil within the horizontal ridges of 30 x 30 x 30 cm dimension (G30) at the depth of 5, 10, and 20 cm is shown in Figure 2. As can be seen in

the figure, the θ increased with depth increment. For all the depths, the highest θ values ($0.330 - 0.420 \text{ cm}^3 \text{ cm}^{-3}$) were spatially distributed along the western and southern side toward the center of the sub-plots, while the lowest θ values ($0.215 - 0.285 \text{ cm}^3 \text{ cm}^{-3}$) were spatially distributed around the eastern – northern corner of the sub-plots. Amongst, the θ values were spatially correlated one to another.

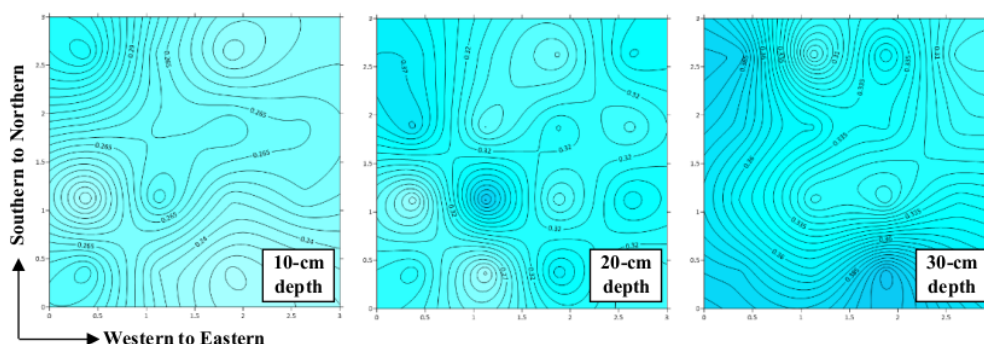


Figure 2. Spatial distribution of the volumetric water content of soil within the horizontal ridges of 30 x 30 x 30 cm dimension (G30) at the depth of 5, 10, and 20 cm.

Figure 3 shows the spatial distribution of the volumetric water content (θ) of soil within the horizontal ridges of 30 x 40 x 30 cm dimension (G40) at the depth of 5, 10, and 20 cm. According to the figure, it can be seen that the θ increased within the depth of 5 to 10 cm and then slightly decreased in the depth of 20 cm, at which the locations were spatially correlated among those depths. For all the depths, the highest θ values ($0.37 - 0.45 \text{ cm}^3 \text{ cm}^{-3}$) were spatially distributed around the eastern – northern, western – southern, and eastern – southern corner of the sub-plots, while the lowest θ values ($0.22 - 0.27 \text{ cm}^3 \text{ cm}^{-3}$) were spatially distributed around the center of the sub-plots.

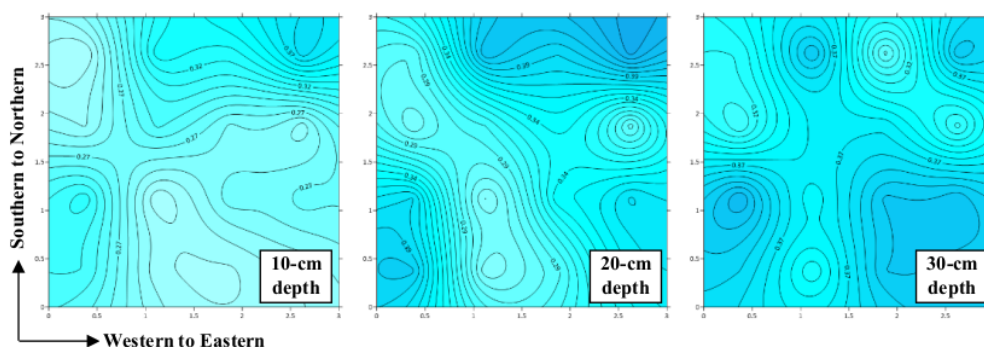


Figure 3. Spatial distribution of the volumetric water content of soil within the horizontal ridges of 30 x 30 x 40 cm dimension (G40) at the depth of 5, 10, and 20 cm.

For the horizontal ridge of 30 x 50 x 30 cm dimension (G50), the spatial distribution of the volumetric water content (θ) of soil within the depth of 5, 10, and 20 cm were spatially correlated from one depth to another, at which the values increased with the depth increment (Figure 4). As shown in the figure, the highest θ values ($0.410 - 0.500 \text{ cm}^3 \text{ cm}^{-3}$) were spatially distributed around the center to southern side of the sub-plots, while the lowest θ values ($0.230 - 0.290 \text{ cm}^3 \text{ cm}^{-3}$) were spatially

distributed along the northern – eastern side of the sub-plots, except those within the depth of 20 cm which were spatially distributed around the eastern side of the sub-plot at the coordinate of [1.5 – 3.0 cm, 1.5 – 2.5 cm].

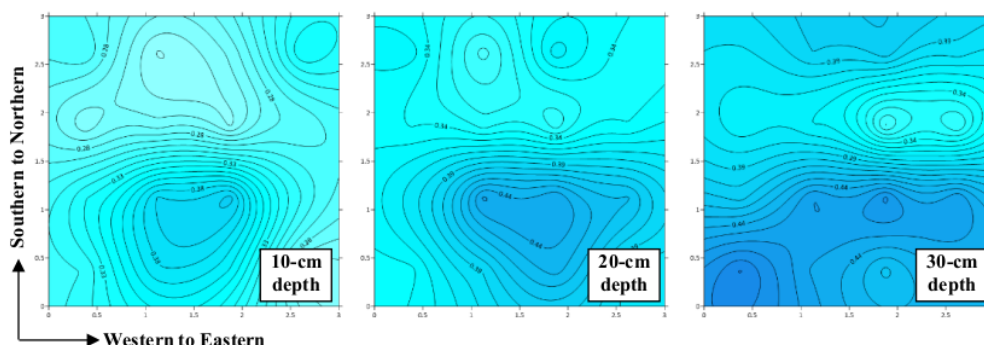


Figure 4. Spatial distribution of the volumetric water content of soil within the horizontal ridges of 30 x 30 x 50 cm dimension (G50) at the depth of 5, 10, and 20 cm.

The correlation of θ spatial distribution pattern among depths indicated that there were a linked of water movement as well as water distribution from one depth to another. The water tended to move and distribute within soil profile in all directions by either infiltration or evapotranspiration [11,12,3,19]. If we took a look more detail, the θ spatial distribution patterns within the upper depths (5 – 10 cm) were more evenly distributed compared to the lower depth (20 cm). This might be affected by the higher uniformity of soil structure at the upper depth than that at the lower depth [14,4,20].

Comparing those 3 dimensions of the horizontal ridges, it was found that the G50 dimension had more homogeneous in θ spatial distribution pattern within all depths than G30 and G40 dimensions. The more complex soil physical (e.g., structure, porosity) and biological (e.g., roots density and distribution, organic matters, microorganism/earthworm) properties existed within wider ridge dimensions [15,7,18,21,22] might corroborate the results.

3.2. Spatial variability of the volumetric water content of soil

To understand the variability of spatial distribution pattern of certain collected data, the spherical model of semivariogram can be applied to the data. There is two main variables in the model, namely semivariance/sill (level or value of variation/variability) and range of influence (distance of variation/variability), by which level/value and distance (degree of dependence/inter-correlated among data pairs) of variation/variability can be characterized respectively.

Figure 5 shows the spatial variability of the volumetric water content (θ) of soil within the horizontal ridges of 30 x 30 x 30 cm dimension (G30) at the depth of 5, 10, and 20 cm. It can be seen from the figure that the θ data at these consecutive depths showed semivarogram trends with semivariance/sill of 0.00084, 0.00327, and 0.00130 $\text{cm}^3 \text{cm}^{-3}$ and distance of 1.216, 0.629 and 1.049 m, respectively. This indicated that the θ data at the top and low profile were spatially correlated with similar level and distance of variation (similar variability), while those at the middle profile had slightly higher variability than others.

For the horizontal ridges of 30 x 40 x 30 cm dimension (G40), the spatial variability of the volumetric water content (θ) of soil at the depth of 5, 10, and 20 cm is presented in Figure 6. According to the figure, the θ data at these consecutive depths had semivarogram trends with semivariance/sill of 0.00324, 0.00429, and 0.00239 $\text{cm}^3 \text{cm}^{-3}$, and distance of 2.809, 1.216 to 0.624 m, respectively. This implied that the θ data were slightly different in level and distance of variation among the depths, by

mean those had different spatial variability one to another. The θ data at the top profile showed higher spatial variability than those at middle and low profile.

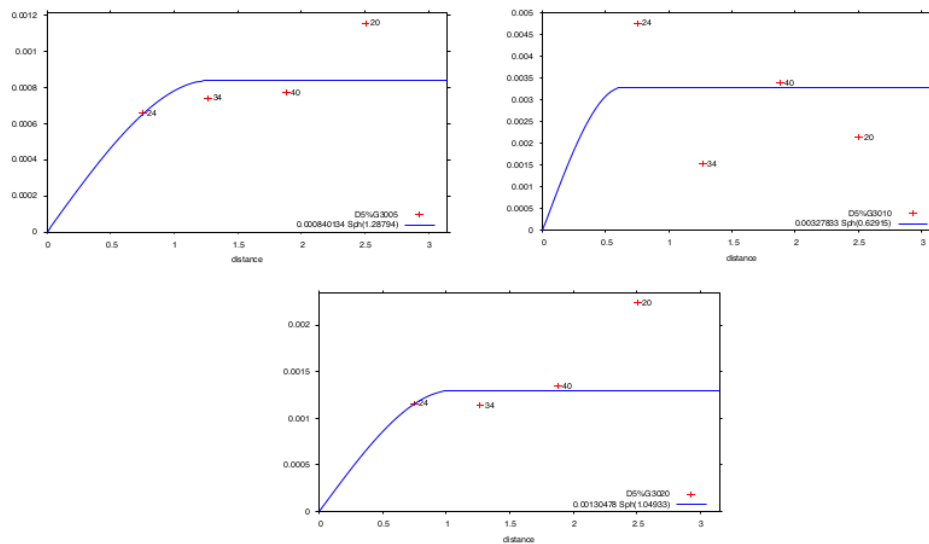


Figure 5. Spatial variability (semivariogram) of the volumetric water content of soil within the horizontal ridges of 30 x 30 x 30 cm dimension (G30) at the depth of 5, 10, and 20 cm.

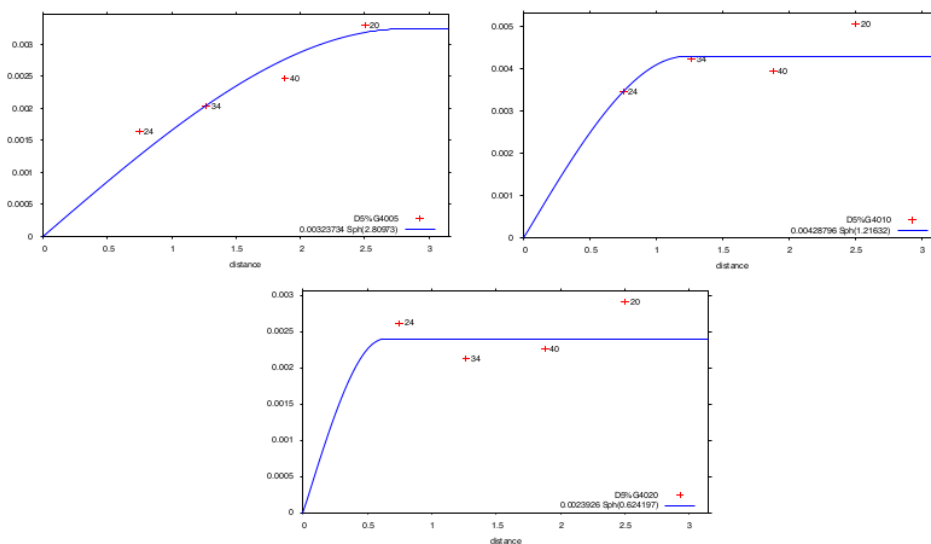


Figure 6. Spatial variability (semivariogram) of the volumetric water content of soil within the horizontal ridges of 30 x 40 x 30 cm dimension (G40) at the depth of 5, 10, and 20 cm.

Figure 7 shows the spatial variability of the volumetric water content of soil within the horizontal ridges of 30 x 50 x 30 cm dimension (G50) at the depth of 5, 10, and 20 cm. As shown in the figure, the θ data at these consecutive depths had semivariogram trends with semivariance/sill of 0.00321, 0.00254, and 0.00331 $\text{cm}^3 \text{cm}^{-3}$, and distance of 1.487, 1.547 to 1.513 m, respectively. This revealed that the θ data were spatially correlated with similar level and distance of variation, by mean those had similar spatial variabilities among the depths.

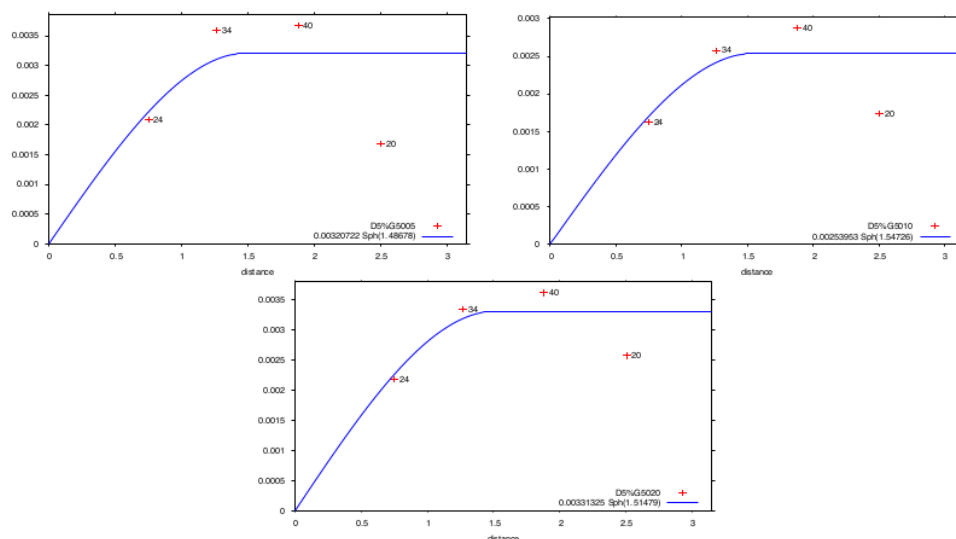


Figure 7. Spatial variability (semivariogram) of the volumetric water content of soil within the horizontal ridges of 30 x 50 x 30 cm dimension (G50) at the depth of 5, 10, and 20 cm.

More specifically, the slightly uniformity in θ spatial variability among the top-low and middle profile (G30, Figure 5) and among all the depths (G40, Figure 6) might be related to the complexity of soil physical (e.g., structure, porosity) and biological (e.g., roots density and distribution, organic matters, microorganism/earthworm) existed at each depth [12,7,20]. The G30 and G40 with relatively narrow ridges width might cause roots development as well as microorganism growth become more concentrated at their middle profiles than the top-low profiles [13,4,19]. This in turn might change the soil structure and water content at the intended profiles more frequent compared to others, thus affected their θ spatial variability.

On the other hand, the G50 with relatively wider ridges width might provide suitable space for roots as well as microorganisms to be better developed and uniformly distributed at all the depths. Accordingly, the soil structure, water content, and density tended to be stably existed at all the entire profiles [6,16,3,14,22]. This revealed that the ridge dimension had remarkable effect on the θ spatial variability.

4. Conclusion

The spatial distribution as well as spatial variability of the volumetric water content (θ) of soil in the horizontal-ridge profile under various ridge dimensions was successfully characterized by applying a Spherical Model in geostatistical analysis. Among the G30, G40, and G50 ridge-dimensions, the θ data at the depth of 5, 10, and 20 cm were in general spatially correlated and had similar spatial pattern from one depth to another, in which the G50 dimension showed more uniform in the θ spatial variability

within all the depths compared to G30 and G40 dimensions. The G50 dimensions allowed the θ data at all the depths to be spatially distributed with relatively similar level and distance of variation, ranged from 0.00254 – 0.00321 cm³ cm⁻³ and 1.487 – 1.547 m, respectively. Therefore, the G50 dimension was considerably applicable for the sustainable potato cultivation in tropical highland with certain interval of drainage channel that might be determined from the above results.

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References

- [1] Badan Pusat Statistik. 2017. *Statistik Tanaman Sayuran dan Buah-buahan Semusim Indonesia 2016*. Badan Pusat Statistik Indonesia, Jakarta (in Indonesian).
- [2] Soleh, M., Arifin, Z., Pratomo, G., Santoso, P., and Nitiawirawan, I.G. 2002. *Sistem Usahatani Tanaman Sayuran untuk Konservasi di Lahan Kering Dataran Tinggi Berlereng*. BPPT Jatim. pp. 1-13 (in Indonesian).
- [3] Wijaya, K., Setiawan, B.I., and Kato, T. 2010. Spatio-temporal Variability of Soil Physical Properties in Different Potato Ridges Designs in Relation to Soil Erosion and Crop Production. *Proceeding of 2010 INWEPF-PAWEES Intl. Joint Symposium*, Jeju-South Korea, 27-29 October 2010.
- [4] Wijaya, K., Kuncoro, P.H., and Arsil, P. 2019. Dynamics of soil physical and chemical properties within horizontal ridges organic fertilizer applied potato land. *IOP Conf. Series: Earth and Environmental Science* **255** (2019) 012024 (doi:10.1088/1755-1315/255/1/012024).
- [5] Comegna, V., Damiani, P., and Somella, A. 2000. Scalling the saturated hydraulic conductivity of a vertic ustorthens soil under conventional and minimum tillage. *Soil and Tillage Research* **54**: 1-9.
- [6] Tominaga, T.T., Cassaro, F.A.M., Bacchi, O.O.S., Reichardt, K., Oliveira, J.C.M., and Timm, L.C. 2002. Variability of soil water content and bulk density in a sugarcane field. *Aust. J. Soil Res.* **40**: 605-614.
- [7] Schwen, A., Bodner, G., Scholl, P., Buchan, G.D., and Loiskandl, W. 2011. Temporal dynamics of soil hydraulic properties and the water-conducting porosity under different tillage. *Soil and Tillage Research* **113**: 89-98.
- [8] Wijaya, K., Nishimura, T., and Kato, M. 2003. Estimation of dry bulk density of soils using amplitude domain reflectometry probe. *J. Jpn. Soc. Soil Phys.* **95**: 63-73.
- [9] Clark, I. 1979. *Practical Geostatistics*. Applied Science Publisher Ltd., London, UK.
- [10] Isaaks, E.H. and Srivastava, R.M. 1989. *An Introduction to Applied Geostatistics*. Oxford University Press, Oxford, USA.
- [11] Miyazaki, T. 1996. Bulk density dependence of air entry suctions and saturated hydraulic conductivities of soils. *Soil Sci.* **161**, 84-90.
- [12] Hillel, D. 1998. *Environmental Soil Physics*. Academic Press, San Diego, USA.
- [13] Kirkham, M.B. 2005. *Principles of Soil and Plant Water Relations*. Elsevier Academic Press, USA.
- [14] Wijaya, K., Nishimura, T., Setiawan, B.I., and Saptomo, S.K. 2010. Spatial variability of soil hydraulic conductivity in paddy field in accordance to subsurface percolation. *J. Paddy Water Environ.* **8**, 113-120.
- [15] Ciollaro, G. and Romano, N. 1995. Spatial variability of the hydraulic properties of a volcanic soil. *Geoderma* **65**: 263-282.
- [16] Wijaya, K., Nishimura, T., Kato, M., and Nakagawa, M. 2004. Field estimation of soil dry bulk density using amplitude domain reflectometry data. *J. Jpn. Soc. Soil Phys.* **97**: 3-12.

- [17] Zhang, J.H., Frielinghaus, M., Tian, G., and Lobb, D.A. 2004. Ridges and Contour Tillage Effect on Soil Erosion from Hillslope in the Sichuan Basin. China. *Journal of Soil and Water Conservation* (On-line). <http://goliath.ecnext.com/>.
- [18] Zhou, L.M., Li, F.M., Jin, S.L., and Song, Y. 2009. How two ridges and the furrow mulched with plastic film affect soil water, soil temperature and yield of maize on the semiarid Loess Plateau of China. *Field Crops Research* 113, 41-47.
- [19] Campbell, G.S. 1985. *Soil Physics with Basic: Transport Model for Soil-Plant Systems*. Elsevier, Amsterdam, p. 49-59.
- [20] Etana, A., Larsbo, M., Keller, T., Arvidsson, J., Schjønning, P., Forkman, J., and Jarvis, N. 2013: Persistent subsoil compaction and its effects on preferential flow patterns in a loamy till soil. *Geoderma* 192, 430-436.
- [21] Utami, F. 2012. Pengaruh Arah Guludan Lahan Terhadap Kadar Air Tanah dan Biomassa tanaman Kentang (*Solanum tuberosum L.*). *Skripsi*. Fakultas Matematika dan Ilmu Pengetahuan Alam, Institut Pertanian Bogor, Bogor (in Indonesian).
- [22] Arya, L.M., Dierolf, T.S., Sofyan, A., Widjaja-Adhi, I.P.G., and van-Genuchten, M.Th. 1998: Field measurement of the saturated hydraulic conductivity of a macroporous soil with unstable subsoil structure. *Soil Sci.* 163(11), 841-852.
- [23] Auerswald, K., Gerl, G., and Kainz, M. 2006. Influence of cropping system on harvest erosion under potato. *Soil and Tillage Research* 89, 22-34.

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