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Optimization of Water Utilization through Identification of Distribution and Types of Water Harvest Infrastructure to Increase Agricultural Production, Study Case in Lampung Province

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ABSTRACT

Indonesian government has promoted the acceleration of local reservoirs development in rural areas. This development shall be integrated in agricultural areas to increase its production. Therefore, identification of the potential location and the type of water harvesting infrastructure are crucial to support and optimize the reservoir construction. Here, this research aims to identify the potential location distribution and the type of water harvesting infrastructure in Lampung Province. A Geographic Information System analysis was conducted using several base maps and thematic maps to extract each region characteristics, which include land use, rice field location, river network, slope, area status, buffer zone, groundwater basin, and rainfall pattern. In addition, a survey was conducted to identify potential water availability and land area, including flow discharge in each region. The results showed that the most suitable types of water harvesting infrastructure were channel reservoirs, followed by river water utilization and shallow wells. All infrastructures are highly dependent on rainfall. This means that channel reservoirs have the largest potential area for irrigation services, followed by the river water utilization, shallow wells, and small reservoirs (*embung*), respectively.

KEYWORDS
channel reservoir, traditional reservoir, water harvesting infrastructure, water saving irrigation, water supply

INTRODUCTION

Potency of water resource in Indonesia is around 3,906,500 million m^3/year (Nugroho et al., 2022), but only less than 20% (691,300 million) is available for further uses (Pambudi, 2021). Water resource that easily accessible for daily human and environment is located at surface water body (such as river and lake) and groundwater. While water body is visible with naked eye, location of groundwater is deep below the surface, which need extra efforts to access (Cai et al., 2020).

In Indonesia, surface water is partially used to support agricultural practices especially for irrigation (Gany et al., 2019; Nurdhawata and Dasanto, 2011). Other uses include industry sector and domestic uses. In changing climate, it is predicted that surface water resources is uncertain (Sýs et al., 2021), which triggers on the competition of water use among various sectors (Alaerts, 2020). This situation will alter a sufficient water supply to meet irrigation requirement on agricultural land in Indonesia (Boer et al., 2007). On other hand, an adequate water has limited agricultural production on dry and rainfed land during dry season (Erythrina et al., 2021). There is a solution to overcome this problem, such as by providing additional water beside rainwater for agricultural irrigation (Liu et al., 2022). One approach to do is by water excess during rainy season by constructing reservoirs and dams

(Kakoulas et al., 2022; Velasco-Muñoz et al., 2019). This approach has been proven to increase agricultural production during the dry season (Bafdal and Dwiratna, 2018; Jo et al., 2021).

In Indonesia, irrigation water becomes main issue as it influences national rice production, and the government has decided that constructing weirs and dams may meet water irrigation (ADB, 2016). These constructions can provide water irrigation for 3 MHa (5% of the total agricultural land) (ADB, 2019). But, the cost for construction is very expensive, which may hamper the fulfillment of water irrigation. Another approach is constructing a small reservoir that is sui-table for agricultural land with a hilly topography (>33 MHa) and flat agricultural lands (>25 MHa) (Firdhauzi et al., 2021; Norma S and Jauhari, 2008; Sumarniasih and Antara, 2021).

Small reservoirs are preferable since they are cheaper to build and can be immediately used for agriculture (Afzal, 2021; Idris et al., 2019). Local dam construction has a lower investment cost, and involves community participation during construction (Schulz et al., 2019). It also provides quick yields (Eshete et al., 2020), inexpensive maintenance (Niu and Shah, 2021), high cobenefits (fishery and agrotourism) (Bezabih, 2021), and is environmentally friendly (Chen et al., 2020; Ioannidou and O'Hanley, 2018).

To promote small reservoirs and other water storage infrastructure construction, Indonesian government has issued a national target to build 30,000 units of small reservoirs (Rejekiningrum and Kartiwa, 2020). This mandate was followed up by the issuance of the Presidential Instruction concerning the acceleration of the small reservoirs and other water storage structures construction in 2017 (BBSDLP, 2017).

Before building small reservoirs and other water storage infrastructures, it is necessary to identify the potential location and the most suitable type of water harvesting infrastucture. To determine the distribution of potential location and type of water harvesting infrastructure, a map can be used to show the presence of indicative locations up to the village level (Rejekiningrum et al., 2005; Rejekiningrum and Kartiwa, 2020; Sixt et al., 2018). Thus, the purpose of the study was to identify the distribu-tion of potential locations and types of water harvest-ing infrastructure to build small reservoirs and other water storage infrastructure in Lampung in order to increase the Planting Index (IP).

RESEARCH METHODS

Data Source

This study was carried out in Lampung, Sumatera. There were two types of data employed in this study, namely primary data and secondary data.

Table 1. Types of data for developing the indicative maps for water harvesting infrastructures

Map	Scale	Sources
Base maps		
Land use map	1: 250,000	National Land Agency Indonesia
Rice field map	1: 250,000	Ministry of Agriculture, Indonesia
River network map	1: 250,000	Indonesian Geospatial Information Agency
Administrative boundary map	1: 250,000	Indonesian Geospatial Information Agency
Area status map	1: 250,000	Ministry of Environment and Forestry, Indonesia
Groundwater basin map	1: 2,000,000	Ministry of Energy and Mineral Resources, Indonesia
Administrative map	1: 250,000	Indonesian Central Bureau of Statistics
DEM SRTM satellite imagery 90 m		United States Geological Survey
Thematic maps		
Distribution map of rainfed rice fields (IP 100)	1: 250,000	Ministry of Agriculture, Indonesia
Dry land map	1: 250,000	Ministry of Agriculture, Indonesia
2 km wide river network buffer zone map	1: 250,000	Indonesian Geospatial Information Agency
Slope map (Slope < 2 %)	1: 250,000	Indonesian Geospatial Information Agency
Map of agricultural cultivation areas (APL: Allocation to other uses)	1: 250,000	Ministry of Agriculture, Indonesia
Village boundary map	1: 250,000	Indonesian Geospatial Information Agency
Groundwater basin map	1: 2,000,000	Ministry of Energy and Mineral Resources, Indonesia
Rainfall pattern map	1: 250,000	Ministry of Agriculture, Indonesia

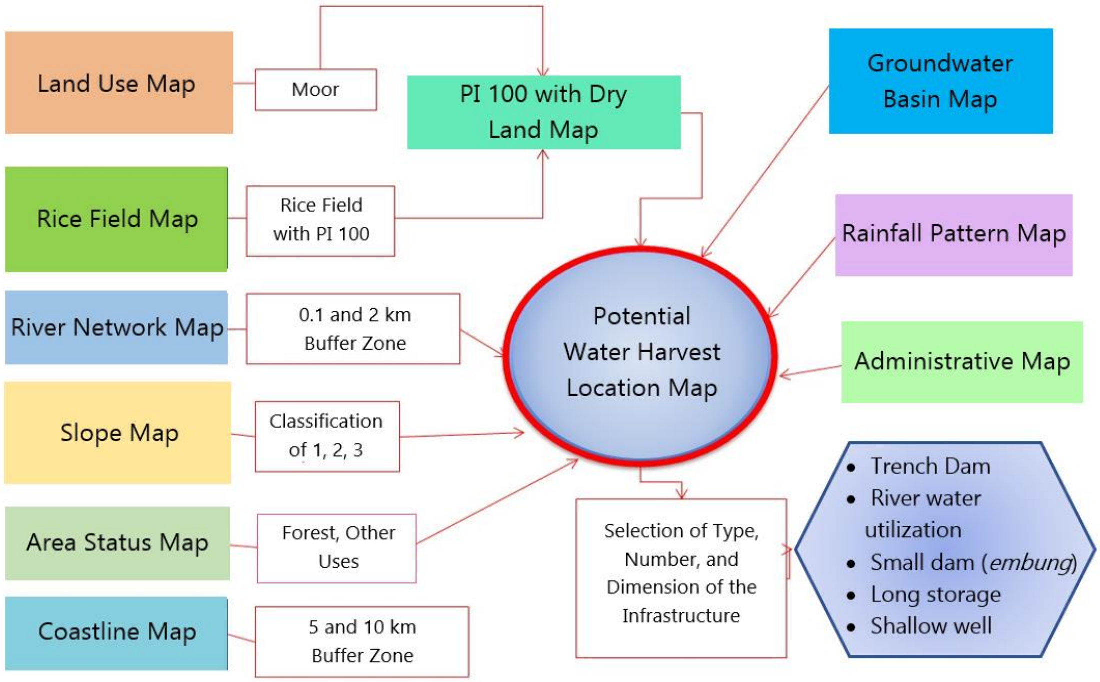

Figure 1. Diagram of the stages of determining the location and selecting the water harvesting infrastructure

The primary data consisted of field observation to estimate the flow discharge and to evaluate the surrounding topography in the area. An interview for the local community was also conducted to provide additional information regarding the available water resource in the region. The secondary data consisted of several base maps and thematic maps, which are presented in Table 1.

Indicative Maps of Potential Location Distribution

The potential location distribution for local dam was identified through an indicative map. The distribution map was constructed using Geographic Information System (GIS) by overlaying base maps and thematic maps in Table 1 and Table 2 using the scheme presented in Figure 2. In addition, a field survey was conducted to gather information regarding the location characteristics including the potential of water availability and land area.

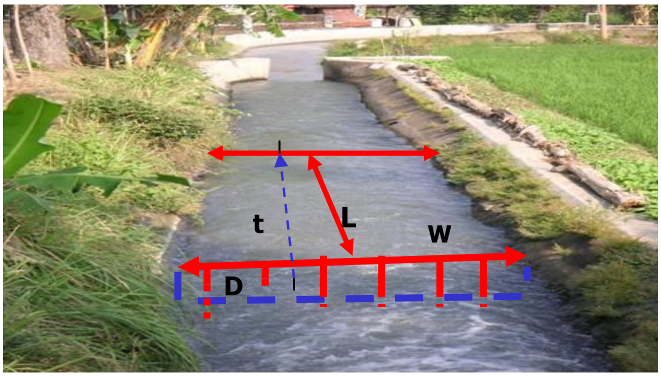

Figure 2. Design of flow discharge measurement in the field

Identification of Water Resources Potential

Water resource potential in a location needs to be identified to select the most suitable water harvesting infrastructure. The water availability poten-tial of surface water such as river stream or irrigation canals is expressed as flow discharge. Flow discharge is the volume of water that passes through the cross-sectional area of the river or canal per unit time. By this definition, the flow discharge was measured by calculating the width and depth of the river, also flow rate. The flow rate was estimated by measuring the time required for an object floating on the surface of the water (wood block, plastic bottles, ping pong balls) to travel from a starting point to a certain point with predetermined distance. The design for flow discharge measurement is shown in Figure 2. Afterwards, the flow rate was calculated using Equation 1.

$$V = \frac{L}{t} \quad (1)$$

Where L is the distance traveled by the floating object from the starting point to the end point (m), t is the time required for the floating object to travel from the starting point to the end point (s), and V is the flow rate (m/s). The estimated flow discharge was then calculated using Equation 2-3.

$$A = W \times D \quad (2)$$

$$Q = V \times A \quad (3)$$

Where Q is the estimated flow discharge (m^3/s), V is the flow rate (m/s), A is the cross-sectional area (m^2), W is the river width (m), and D is the average river depth (m).

Table 3. Criteria in determining water harvesting infrastructure (Kartiwa et al., 2017)

Parameter	Existing Condition	Water Harvesting Infrastructure
Water source type: river stream	Minimum discharge > 50 l/s, river width < 18 m, depth < 1.5 m, difference in elevation of water source and land < 2 m, distance between river and land area < 2 km.	Channel Reservoir
Water source type: river stream, irrigation, lake	Minimum discharge > 25 l/s, river width > 18 m, depth > 1.5 m, difference in elevation of water source and land > 2 m, source distance and land area < 100 m	River Water Utilization (Pumping)
Water source type: rainfall, drainage channels, intermittent rivers (rivers that is dry during the dry season)	The surrounding topography is hilly land which is a water catchment area, close to drainage channels or intermittent rivers.	Channel Reservoir
Water source type: rainfall, drainage channels, intermittent rivers, tidal rivers	The surrounding topography is flat, close to drainage channels, intermittent rivers, or tidal rivers	Long Storage
Water source type: groundwater	Ground water depth < 20 m	Shallow well

Another important information regarding water resources potential is the minimum flow rate during dry season. Initial information on water availability in the dry season was gathered through interview with local community. The interview also aimed to collect information on fluctuations in seasonal water availability.

Identification of the groundwater availability potential was carried out in locations without surface water resources. This was performed through topo-graphy or landform observations and the presence of local wells. Commonly, locations with potential groundwater availability are flat land sur-rounded by mountains or hills. Further identi-fication was carried out by measuring the water level of the local wells. Additional information was gathered from interviews regarding the change in seasonal water level.

Identification of Potential Area of Irrigated Land

Identification of the potential area of irrigation services was carried out by considering the total land area, land cover, as well as land slope. The total land area and land cover were specified from the total area of rice field and secondary crops in the region. The land slope was specified from the elevation difference between the water surface and the land, which was measured during field observation. The slope information is important to determine pump specifi-cations for potential irrigation.

Afterwards, estimated potential area for irrigation service was calculated according to water demand. The water demand was based on crop water requirement for lowland rice cultivation, which is 1 l/sec/ha, while for secondary crops is 0.8 l/sec/ha.

Selection of Most Suitable Water Harvesting Infrastructure

The type of water harvesting infrastructure is selected by considering several factors, including the estimated flow discharge, slope, topography, and potential area of irrigated land. The selection process was carried out according to the criteria as listed in Table 3. A more detailed stage to the selection process is shown in Figure 2.

RESULTS AND DISCUSSION

The results of the analysis and the potential area of irrigation services in Lampung for each regency are presented in Table 4 and Table 5 and Figures 3. Table 4, Figure 3, and Figure A1 showed that the water har-

Table 4. Types of infrastructure and wide potential of irrigation services in Lampung Province

Water Harvesting Infrastructure	Units	Potential Irrigated Area (Ha)
Channel Reservoir (Dam Parit)	811	458,891
River Water Utilization	770	78,516
Small Reservoir (*Embung*)	32	5,061
Long Storage	-	-
Shallow Well	447	39,179
Total	2,060	581,646

Table 5. Types of water harvesting infrastructure and potential irrigated area in each Regency in Lampung Province

Region/City	Channel Reservoir		Small Reservoir		River Water Utilization		Shallow Well	
	Unit	Potential Irrigated Area (Ha)	Unit	Potential Irrigated Area (Ha)	Unit	Potential Irrigated Area (Ha)	Unit	Potential Irrigated Area (Ha)
Bandar Lampung	6	894			11	637	7	145
West Lampung	55	45,427			41	3,817	32	3,219
South Lampung	45	9,471			68	6,971	33	1,373
Central Lampung	179	97,082			171	19,120	87	3,049
East Lampung	103	51,667			85	7,053	96	18,714
North Lampung	60	23,627			65	5,640	43	1,991
Mesuji	61	49,168	23	3,713	49	6,334		
Metro	2	245			4	131	1	15
Pesawaran	8	2,982			19	1,343	4	79
Pringsewu	4	481			5	213		
Tanggamus	29	45,518			21	2,927	14	1,435
West Tulangbawang	61	39,015	1	90	54	7,014	23	1,703
Tulangbawang	104	57,253	7	1,208	98	8,633	25	1,453
Way Kanan	94	36,060	1	50	79	8,683	82	6,003
Total	811	458,891	32	5,061	770	78,516	447	39,179

vesting infrastructure with the largest potential area for irrigation services in the entire Lampung is channel reservoir, as many as 811 units with potential irrigated area of 458,891 Ha. This was followed by 770 units of river water utilization with potential irrigated area of 78,516 Ha, 447 units of shallow wells with potential irrigated area of 39,179 Ha, and 32 units of small reservoirs with potential irrigated area of 5,061 Ha. Table 5, Figure 3, and Figure A1 presented more detailed information regarding each type and distribution of water harvesting infrastructure, including the number of units and the potential irrigated area up to the district level in Lampung.

The results also showed that the water harvesting infrastructure most suitable and likely to be developed in Lampung, indicated by the largest potential irrigated area are channel reservoirs, followed by river water utilization, shallow wells, and small reservoirs, respectively. However, these water infrastructures are highly dependent on rainfall.

In contrast with the majority, in the districts of Mesuji, Tulang Bawang Barat, Tulang Bawang, and Way Kanan, the most suitable water harvesting infrastructure was small reservoir, followed by channel reservoirs and river water utilization. Additionally, Mesuji and Pringsewu districts may have the potential for the construction of channel reservoirs and river water utilization, but not for shallow wells.

Water harvesting technology implementation for supplementary irrigation such as small reservoir, channel reservoirs, long storage, river water utilization, shallow well (< 50 m), deep well (50-100 m), and water-saving irrigation are vital in a limited water condition (Heryani and Rejekiningrum, 2020; Setiobudi and Sembiring, 2009). This was reinforced by previous finding in Tompobulu, Maros, where a channel reservoir with a width of 60 m can provide irrigation services of for up to 75 ha land. From the cost aspect, the construction of the channel reservoir required 150 million rupiah. With this investment, in one year, the additional production obtained was 1,230 tons of harvested dry grain or equivalent to Rp. 4.55 billion. Additionally, with the help of the channel reservoir, Tompobulu had increased the planting index from 1.0 to 2.0 (Sosiawan et al., 2017). Similarly, reservoirs in Tenjo, Bogor, also reported to provide irrigation services for total area of 45 ha. The construction required cost of 100 million rupiah, with additional production obtained within 1 year is 135 tons of harvested dry grain or equivalent to Rp. 500 million. After the construction of the reservoir, farmer in Ciomas received an additional planting index of 0.5 (Rejekiningrum and Kartiwa, 2020).

Water harvesting infrastructure is used as supplementary irrigation service to irrigate agricultural land during the dry season, both for food crops (rice or secondary crops) and horticultural commodities (vegetables). Due to the limited volume of available water in reservoirs, the water utilization must be carried out efficiently. Several water utilization techni-

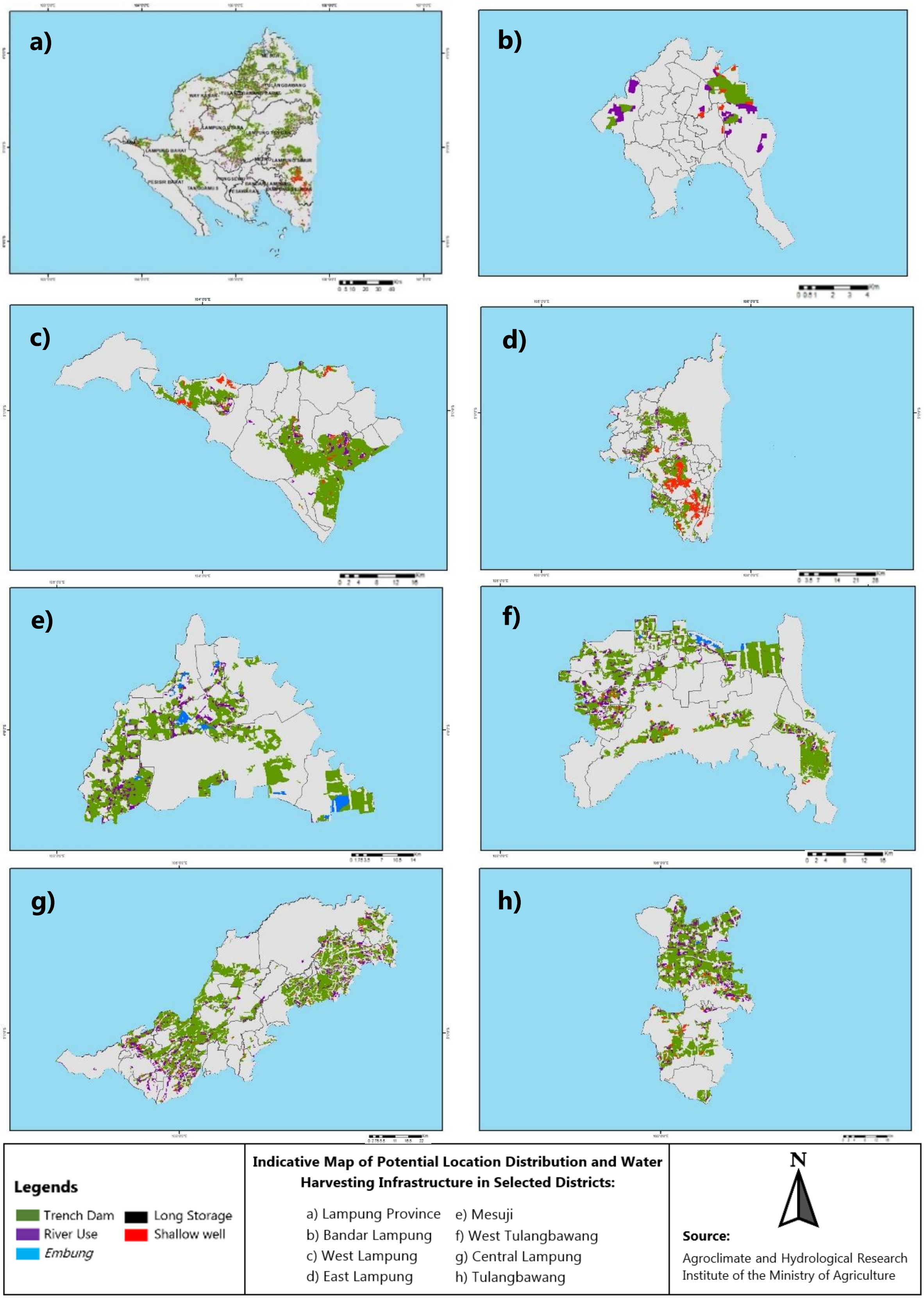

Figure 3. Indicative maps of potential location and type of water harvesting infrastructures in Lampung Province (a), and in (b) Bandar Lampung; (c) West Lampung; (d) East Lampung; (e) Mesuji; (f) West Tulangbawang; (g) Central Lampung; and (h) Tulangbawang

ques have been implemented, namely drip irrigation systems, piping, and open flow irrigation systems or irrigation channels. The water used from the reservoir to irrigate rice, is directed to irrigate only during certain times, such as during the primordia stage, flowering, and grain filling. In addition, the irrigation is stopped after the soil reaches a saturated condition (Tamburino et al., 2020).

Previous finding by Bitterman et al., (2016) revealed that small reservoir in Tamil Nadu, India can support agricultural livelihoods, reduce water stress, and preserve surrounding ecosystems. Similar research in China also reported that harvesting water may increase soil moisture in rainfed highland (Ding et al., 2021). Another research by Hamdani et al., (2016) in Maros, South Sulawesi, showed that rain and groundwater harvesting technology such as channel reservoir can increase cropping intensity from the rice-fallow-fallow cropping pattern to rice-peanut-fallow and rice-watermelon-fallow. This also indicated that there was an increase in farmer income after the construction of the channel reservoir. Farmers would find the benefits of the channel reservoir construction and further act responsible to maintain the continuity of the channel reservoir function.

Increasing cropping index from 100 to 300 can be supported by water harvesting infrastructure construction such as channel reservoir, river water utilization, shallow well, or small reservoir in the targeted area. The development of water harvesting infrastructure that is built close to water sources is expected to meet crop water needs by providing water supply of 1 liter/sec. The water management pattern or managing water addition into the reservoir using existing water resources can extend the planting period and expand the planted area. Afterwards, this may result in increased planting index and farmers can open new agricultural land according to the new water availability (Tamburino et al., 2020).

CONCLUSIONS

Types of water harvesting infra-structure that could be widely developed in Lampung are channel reservoirs, followed by river water utilization, and shallow wells or shallow groundwater, all of which are highly dependent on rainfall. This means that channel reservoirs had the largest potential area for irrigation services in Lampung, followed by the river water utilization, shallow wells, and small reservoirs, respectively.

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REFERENCES

ADB, 2019. Policies to Support Investment Requirements of Indonesia's Food and Agriculture Development during 2020-2045. Asian Development Bank.

ADB, 2016. River Basin Management Planning in Indonesia: Policy and Practice. Asian Development Bank.

Afzal, M.K., 2021. Economic evaluation of small dams in rain-fed region of Pothwar Plateau, Pakistan. Cogent Food & Agriculture 7, 1942403. https://doi.org/10.1080/23311932.2021.1942403

Alaerts, G.J., 2020. Adaptive policy implementation: Process and impact of Indonesia's national irrigation reform 1999–2018. World Development 129, 104880. https://doi.org/10.1016/j.worlddev.2020.104880

Bafdal, N., Dwiratna, S., 2018. Water Harvesting System as an Alternative Appropriate Technology to Supply Irrigation on Red Oval Cherry Tomato Production. International Journal on Advanced Science, Engineering and Information Technology 8, 561–566.

BBSDLP, 2017. Reorientasi Kebijakan Pengembangan Infrastruktur Irigasi Nasional. BBSDLP, Bogor.

Bezabih, A.W., 2021. Evaluation of small hydropower plant at Ribb irrigation dam in Amhara regional state, Ethiopia. Environmental Systems Research 10, 1. https://doi.org/10.1186/s40068-020-00196-z

Bitterman, P., Tate, E., Van Meter, K.J., Basu, N.B., 2016. Water security and rainwater harvesting: A conceptual framework and candidate indicators. Applied Geography 76, 75–84. https://doi.org/10.1016/j.apgeog.2016.09.013

Boer, R., Rahadiyan, M.K., Perdinan, P., 2007. The Use of Agriculture System Modeling for Crop Management: Case Study in Pusaka Negara. Agromet 21, 1. https://doi.org/10.29244/j.agromet.21.2.1-11

Cai, Z., Wang, W., Zhao, M., Ma, Z., Lu, C., Li, Y., 2020. Interaction between Surface Water and Groundwater in Yinchuan Plain. Water 12, 2635. https://doi.org/10.3390/w12092635

Chen, A., Wu, M., McClain, M.E., 2020. Classifying Dams for Environmental Flow Implementation in China. Sustainability 12, 107. https://doi.org/10.3390/su12010107

Ding, W., Wang, F., Dong, Y., Jin, K., Cong, C., Han, J., Ge, W., 2021. Effects of rainwater harvesting system on soil moisture in rain-fed orchards on the Chinese Loess Plateau. Agricultural Water Management 243, 106496. https://doi.org/10.1016/j.agwat.2020.106496

Erythrina, E., Anshori, A., Bora, C.Y., Dewi, D.O., Lestari, M.S., Mustaha, M.A., Ramija, K.E., 2021. Assessing Opportunities to Increase Yield and Profit in Rainfed Lowland Rice Systems in Indonesia. Agronomy 11, 777. https://doi.org/10.3390/agronomy11040777

Eshete, D.G., Sinshaw, B.G., Legese, K.G., 2020. Critical review on improving irrigation water use efficiency: Advances, challenges, and opportunities in the Ethiopia context. Water-Energy Nexus 3, 143–154. https://doi.org/10.1016/j.wen.2020.09.001

Firdhauzi, S., Semedi, M., Damayanti, A., Dimyati, M., 2021. Spatial and Temporal Pattern of Soil Conservation in Mountain Ecosystem: Case Study of Patuha Mountain, West Java - Indonesia. GEOMATE 19, 43–48.

Gany, A.H.A., Sharma, P., Singh, S., 2019. Global Review of Institutional Reforms in the Irrigation Sector for Sustainable Agricultural Water Management, Including Water Users' Associations. Irrigation and Drainage 68, 84–97. https://doi.org/10.1002/ird.2305

Hamdani, A., Talaohu, S.H., Heryani, N., 2016. Pengembangan Teknologi Panen Hujan dan Aliran Permukaan: Analisis Usahatani Pemanfaatan Sumberdaya Air. Jurnal Pengkajian dan Pengembangan Teknologi Pertanian 19, 153–165. https://doi.org/10.21082/jpptp.v19n2.2016.p153-165

Heryani, N., Rejekiningrum, P., 2020. Pengembangan Pertanian Lahan Kering Iklim Kering Melalui Implementasi Panca Kelola Lahan. Jurnal Sumberdaya Lahan 13, 63–71. https://doi.org/10.21082/jsdl.v13n2.2019.63-71

Idris, A.M.S., Permadi, A.S.C., Sianturi, U.M., Hazet, F.A., 2019. Strategic Issues in Dam Operation and Maintenance in Indonesia. 1 3, 225–238. https://doi.org/10.36574/jpp.v3i2.76

Ioannidou, C., O'Hanley, J.R., 2018. Eco-friendly location of small hydropower. European Journal of Operational Research 264, 907–918. https://doi.org/10.1016/j.ejor.2016.06.067

Jo, Y.-J., Song, J.-H., Her, Y., Provolo, G., Beom, J., Jeung, M., Kim, Y.-J., Yoo, S.-H., Yoon, K.-S., 2021. Assessing the Potential of Agricultural Reservoirs as the Source of Environmental Flow. Water 13, 508. https://doi.org/10.3390/w13040508

Kakoulas, D.A., Golfinopoulos, S.K., Koumparou, D., Alexakis, D.E., 2022. The Effectiveness of Rainwater Harvesting Infrastructure in a Mediterranean Island. Water 14, 716. https://doi.org/10.3390/w14050716

Kartiwa, B., Rejekiningrum, P., Sosiawan, H., Sutrisno, N., 2017. Petunjuk Teknis: Implementasi Infrastruktur Panen Air. Badan Penelitian dan Pengembangan Pertanian, Bogor.

Liu, X., Liu, W., Tang, Q., Liu, B., Wada, Y., Yang, H., 2022. Global Agricultural Water Scarcity Assessment Incorporating Blue and Green Water Availability Under Future Climate Change. Earth's Future 10, e2021EF002567. https://doi.org/10.1029/2021EF002567

Niu, Y., Shah, F.A., 2021. Economics of Optimal Reservoir Capacity Determination, Sediment Management, and Dam Decommissioning. Water Resources Research 57, e2020WR028198. https://doi.org/10.1029/2020WR028198

Norma S, M., Jauhari, S., 2008. Pemanfaatan Sumber Air Pegunungan untuk Mengantisipasi Kekeringan pada Musim Kemarau untuk Tanaman Kubis. Agromet 22, 174–181. https://doi.org/10.29244/j.agromet.22.2.174-181

Nugroho, H.Y.S.H., Indrawati, D.R., Wahyuningrum, N., Adi, R.N., Supangat, A.B., Indrajaya, Y., Putra, P.B., 2022. Toward Water, Energy, and Food Security in Rural Indonesia: A Review. Water 14, 1645. https://doi.org/10.3390/w14101645

Nurdhawata, S., Dasanto, B.D., 2011. Analisa Potensi Waduk Rukoh dalam Memenuhi Kebutuhan Air di Kabupaten Pidie, Indonesia. Agromet 25, 9–16. https://doi.org/10.29244/j.agromet.25.1.9-16

Pambudi, A.S., 2021. Overview and evaluation of the Indonesia's water resources management policies for food security. Indonesian Journal of Applied Environmental Studies 2, 84–93. https://doi.org/10.33751/injast.v2i2.3586

Rejekiningrum, P., Kartiwa, B., 2020. Kontribusi Pembangunan Infrastruktur Panen Air Terhadap Peningkatan Pendapatan Dan Kesejahteraan Petani. Risalah Kebijakan

Pertanian dan Lingkungan 7, 37–51. https://doi.org/10.29244/jkebijakan.v7i1.28073

Rejekiningrum, P., Ramadani, F., Apriyana, Y., Haryono, 2005. Identifikasi dan Karakterisasi Potensi Air Tanah untuk Pengembangan Irigasi Suplementer di Pabrik Gula Rendeng dan Trangkil Jawa Tengah. Agromet 19, 49–64. https://doi.org/10.29244/j.agromet.19.1.49-64

Schulz, C., Martin-Ortega, J., Glenk, K., 2019. Understanding Public Views on a Dam Construction Boom: the Role of Values. Water Resour Manage 33, 4687–4700. https://doi.org/10.1007/s11269-019-02383-9

Setiobudi, D., Sembiring, H., 2009. Increasing Water Productivity of Lowland Rice through the Water Saving Techniques and Crop Management in Response to Drought. Agromet 23, 123–147. https://doi.org/10.29244/j.agromet.23.2.123-147

Sixt, G.N., Klerkx, L., Griffin, T.S., 2018. Transitions in water harvesting practices in Jordan's rainfed agricultural systems: Systemic problems and blocking mechanisms in an emerging technological innovation system. Environmental Science & Policy 84, 235–249. https://doi.org/10.1016/j.envsci.2017.08.010

Sosiawan, H., Sudarman, K., Kartiwa, B., 2017. Pendalaman Identifikasi Wilayah Potensial Pengembangan IP-300 Berdasarkan Peta Potensi Pengembangan Kawasan Pertanian PJKU untuk Penyusunan Strategi Optimalisasi Pemanfaatannya., in: Laporan Akhir Kegiatan on Top Perubahan Iklim. Balai Penelitian Agroklimat dan Hidrologi, Badan Litbang Pertanian Bogor, Bogor.

Sumarniasih, M.S., Antara, M., 2021. Sustainable dryland management strategy in Buleleng Regency of Bali, Indonesia. JODA 7, 88–95. https://doi.org/10.5897/JODA2020.0064

Sýs, V., Fošumpaur, P., Kašpar, T., 2021. The Impact of Climate Change on the Reliability of Water Resources. Climate 9, 153. https://doi.org/10.3390/cli9110153

Tamburino, L., Di Baldassarre, G., Vico, G., 2020. Water management for irrigation, crop yield and social attitudes: a socio-agricultural agent-based model to explore a collective action problem. Hydrological Sciences Journal 65, 1815–1829. https://doi.org/10.1080/02626667.2020.1769103

Velasco-Muñoz, J.F., Aznar-Sánchez, J.A., Batlles-delaFuente, A., Fidelibus, M.D., 2019. Rainwater Harvesting for Agricultural Irrigation: An Analysis of Global Research. Water 11, 1320. https://doi.org/10.3390/w11071320

ANNEX

Figure A1. Indicative maps of potential location and type of water harvesting infrastructures in selected districts in South Lampung (a), and in (b) North Lampung; (c) Metro; (d) Pesawaran; (e) West Pesisir; (f) Pringsewu; (g) Tanggamus; (h) Way Kanan