Model of Farmer's Adaptation Capacity in Facing Climate Change: Integration of Numerical Indicators and Local Specific Indicators In *Subak*

I Putu Sriartha[1], I Wayan Krisna Eka Putra[2], Made Dwipayana[3], Kadek Rudiana[4], I Made Widnyana Pramana Putra[5]

{putu.sriartha@undiksha.ac.id[1], krisna.ekaputra@undiksha.ac.id[2], made@undiksha.ac.id[3], rudiana@undiksha.ac.id[4], widnyana.pramana@undiksha.ac.id[5]}

Universitas Pendidikan Ganesha, Indonesia[1,2,3,4,5]

Abstract This research aims to analyze the adaptive capacity of irrigated rice farmers in facing climate change through the integration of subak local specific indicators and numerical indicators. The research located in Sawan District, Buleleng Regency, Bali. The research used a descriptive survey type design. The research sample was determined by two subaks in each zone, namely the upstream zone, middle zone and downstream zone randomly. In each subak sample, 3 leaders and 2 subak members were taken purposively. Data was collected using interviews, observation, documentation techniques and analyzed descriptively using an index. This research produce a pentagonal model of the adaptive capacity of farmers. The average farmer capacity index is at a high level. Two specific local indicators sourced from Subak's local wisdom, namely sociocultural capital and Subak's physical infrastructure capital, have the highest index, while 3 three numerical indicators have low indices. The implication of the research results is the importance of strengthening and integrating local specific indicators and numerical indicators in analyzing the adaptive capacity of irrigated rice farmers

Keywords: Adaptive capacity; climate change; rice field farmers; Subak.

ICLSSE 2024, October 17, Singaraja, Indonesia

DOI 10.4108/eai.17-10-2024.2353702

1. Introduction

Food agriculture, especially irrigated rice fields, is one of the sectors most vulnerable to the impacts of climate change, because the success of this staple food production process is very dependent on the carrying capacity of the climate, especially air temperature and rainfall [1]. Currently, the global climate is experiencing changes towards an extreme climate, which is characterized by an increase in the frequency and intensity of extreme weather events, changes in rain patterns, and increases in temperature and sea water levels [2]. The Intergovernmental Panel on Climate Change (IPCC) published that the earth's temperature has increased by around 0.8°C over the last century, and in the last three decades conditions have been hotter than in the previous decade. This condition is triggered by increasing greenhouse gas (GHG) emissions, such as carbon dioxide, methane, nitrogen oxide and a number of industrial gases, as a result of the population explosion and modernization which drives deforestation and other activities. Currently, the concentration of CO_2 gas in the earth's atmosphere is the highest in history, which is 40% higher than in the pre-industrial era [3].

Global climate change has a multidimensional impact on human life, and the biggest threat is the agricultural sector of food crops (rice). Increasing temperatures and erratic rain patterns cause a decrease in plant productivity, encouraging the explosion of plant pest organisms. In coastal areas, causes sea levels and salinity to rise, which has an impact on decreased production and reduced agricultural land in coastal areas [4];[5];[3]. The regions of Java and Bali are most impacted by global climate change, because these two regions are centers for irrigated rice crops with the highest productivity in Indonesia. Irrigated rice farming in Bali has a very strategic role, not only as a supplier of rice production, but also as a supporter of social and cultural life with its unique subak local wisdom. However, currently Subak's irrigated rice fields are being threatened by the rapid development of tourism and climate change, which has an impact on the massive conversion of rice fields, scarcity of irrigation water, flooding and the explosion of pests and diseases [6]. This problem has an impact on reducing crop yields and farmer's income. Nuryanti, L., & Waryanto, B. [8] in [10] reported that in the 2014-2020 period the harvest area, production and productivity of rice in Bali decreased sharply, respectively 37.20%, 44.08% and 2.64%. The high risk of losses in irrigated rice farming due to climate change in Bali has implications for the importance of studying farmers' adaptive capacity. Data and information regarding determining indicators farmers' adaptive capacity is useful as a basis for strengthening adaptive capacity, establishing effective strategies and programs in accordance with the characteristics of farmers' local environment.

Adaptive capacity is a concept that has multidimensional indicators. [11] in [10] define adaptive capacity as "the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences". According to [12] in [10] there are several other terms that have similar meanings to the concept of adaptive capacity, such as adaptability, coping ability, management capacity, stability, flexibility, and resilience. One approach that is often used in measuring adaptive capacity is the sustainable livelihoods approach which consists of 5 asset components, namely: human, social, natural, physical and financial capital [15; 16; 18;10]. In implementing this approach, not many have integrated it with local environmental characteristics. According [13; 14] in [10] stated that the characteristics of adaptation that are contextual and specific, determined by the sociocultural, economic and geographical environment. This has consequences for the importance of integrating local specific indicators in the analysis of farmers' adaptive capacity to ensure effective adaptation action strategies.

The agricultural system of the Balinese people is uniquely local, namely that its management is carried out by traditional farmer organizations known as subak. Subak's role is very strategic in supporting food security, especially rice, preserving the environment and maintaining Balinese socio-cultural values based on the *Tri Hita Karana* philosophy. The meaning of Tri Hita Karana is three components which are believed to be the cause of achieving happiness in human life, namely *parhyangan* (maintaining a harmonious relationship with God), *pawongan* (creating harmonious relationships with fellow humans), and *palemahan* (maintaining harmonious relationships with nature). Subak is based on the Tri Hita Karana philosophy in managing irrigation water, land and plants guided by religious, socio-cultural and ecological values.

2 Methods

The research design used is descriptive survey type research. The research was conducted in Sawan District, the area that has the largest area of rice fields in Buleleng Regency, Bali. Measuring adaptation capacity in this research uses a sustainable livelihood framework approach which is integrated with the specific local conditions of the irrigated rice farming system in Bali, namely the local wisdom of Subak which is based on the Tri Hita Karana philosophy. Based on this integration, farmers' adaptive capacity is measured by 5 indicators, namely human capital, financial capital, natural capital, socio-cultural capital and physical infrastructure capital of Subak. The last two indicators are local specific indicators that originate from the Tri Hita karana subak philosophy (*parhyangan* = cultural; *pawongan* = social, *palemahan* = physical infrastructure). Each indicator is further described into 5 sub-indicators (Table 1).

Table 1. Indicators and Sub-indicators for Measuring Farmers' Adaptation Capacity.

Indicators	**Sub-Indicators**	**Type of Data**
Natural capital	a. Topography of rice fields	Ordinal

	b.Jenis lahan sawah	Ordinal
	c.Area of rice fields	Interval
	d. Duration of irrigation water supply	Ordinal
	e. Irrigation water quality	Ordinal
Human capital	a. Knowledge about climate change	Interval
	b. Commitment to rice fields and profession	Interval
	c. Perceptions of climate change	Interval
	d.Formal Education	Ordinal
	e.Farmer age	Ratio
Finansial capital	a.Rice fields productivity	Interval
	b. Farmer business activities	Ordinal
	c. Ownership of farmer assets	Ordinal
	d.Access to credit	Ordinal
	e.Access to market	Ordinal
Socio-cultural capital	a. Participation in subak ritual activities	Ordinal
	b. Participation in mutual cooperation activities	Ordinal
	c. help each other in farming	Ordinal
	d. Compliance to *awig-awig* (customary law) of subak	Ordinal
	e.Subak leadership	Ordinal
Phisical infrastructure capital of subak	a. Function of the Subak irrigation network	Ordinal
	b. The function of the subak holy place (*pura*).	Ordinal
	c.Subak road access	Ordinal
	d. Access to information, communication and technology	Ordinal
	e. Subak office (*bale*) function	Ordinal

The research population was all subaks in Sawan District, totaling 63 subaks. Considering the physiography of the research area which extends from the mountains in the south to the sea in the north, the sample was divided into three zones and 2 subaks were randomly selected from each zone. Based on this method, the upper zone subak samples were *Subak Juwuk* (Sudaji Village) and *Subak Bingin* (Galungan Village), the middle zone samples were *Subak Bongkang* and *Subak Babahan* (Menyali Village), the lower zone samples were *Subak Yeh Lembu* (Bungkulan Village) and *Subak Babakan* (Kerobokan Village). The subjects who became informants were 3 subak administrators and 3 farmer members for each subak sample, so the total number of informant subjects was 36 people. There are various types of data for measuring adaptation capacity (interval, ordinal, ratio), for this reason the data will be standardized into an index with the following formula (Figure 1).

$$\text{ACI} = \frac{\text{score aktual } - \text{score minimum}}{\text{score maksimum } - \text{score minimum}} \qquad (\text{Figure 1})$$

ACI = Adaptive Capacity Index.

Based on the index value which moves from 0 to 1, the adaptation capacity assessment criteria are then created into 4 levels, namely: very low (index 0 – 0.24), low (index 0.25 – 0.49), high (index 0.50 -0.74), and very high (0.75 -1.0). Data was collected using interview, observation and documentation techniques, then analyzed using descriptive techniques through the stages of scoring, categorization, data tabulation, description and discussion of research results.

3 Results and Discussion

The adaptive capacity of irrigated rice farmers are interpreted as the farmer's ability to know, be aware, prepare and adapt to facing climate change. This ability is represented through the ownership of resources which become the life capital of irrigated rice farmers. Based on 5 indicators and 25 measurement sub-indicators, the research results regarding the index value of each indicator and sub-indicator of adaptive capacity are shown in Table 2, and pentagonal model of farmers' adaptive capacity based on the index values of the 5 indicators as in Figure 1.

Table 2. Index Values of Farmers' Adaptation Capacity Indicators and Sub-indicators.

No	Indicators	Sub-indicator index values					Mean of Indicators Index Values
		a	b	c	d	e	
1	Natural Capital	0,38	0,40	0,23	0,31	0,70	0,40
2	Human Capital	0,51	0,57	0,50	0,44	0,33	0,47
3	Socio-cultural Capital	0,73	0,57	0,71	0,62	0,48	0,62
4	Finansial Capital	0,56	0,32	0,40	0,35	0,58	0,44
5	Phisical infrastructure capital of subak	0,58	0,63	0,53	0,45	0,60	0,56

Source: Research Result, 2022,

Note: the meaning of the letters a, b, c, d, e, according to those listed in Table 1.

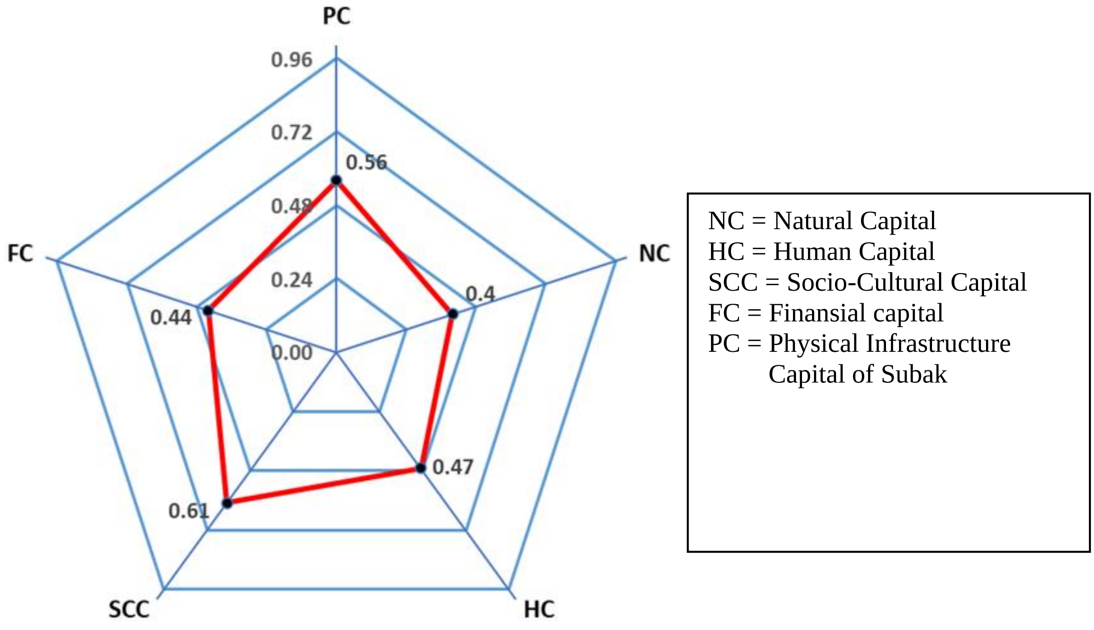

Figure 1. Pentagonal model of farmers' adaptive capacity based on the index values of the 5 indicators (red color line).

Overall, the adaptive capacity index value of lowland rice farmers is 0.50. This shows that the adaptive capacity of irrigated rice farmers in facing climate change is at a high level. Two indicators have high index values, namely: socio-cultural indicators and physical infrastructure of Subak which are local specific indicators, while the other 3 indicators which are numerical have low index values. This study indicate that subak as the local wisdom of Balinese farming communities has a positive role in increasing farmers' adaptive capacity in facing climate change. Farmers' adaptive capacity determines the adaptation strategy actions that will be taken. [20] and [17] stated that farmers' high adaptive capacity allows them to carry out various adaptation strategy actions, and vice versa. Thus, strengthening the socio-cultural values and traditional physical infrastructure of Subak will encourage farmers to make various adaptation strategy options in facing climate change.

Natural capital indicators in the form of regional topography, type of paddy field, area of paddy field and water supply for irrigation do not support farmers' adaptive capacity. The most critical natural capital experienced by farmers is the average rice field ownership of 27 acres and the supply of irrigation water is very limited, especially in the dry season. Low ownership of paddy fields can cause a decrease in farmers' efforts and actions to choose various adaptation strategies. [21]states that there is a significant influence between ownership of rice fields and farmers' decisions to carry out various adaptation strategy options in facing climate change. This is confirmed by [22] that the determining factors for the sustainability of the lowland rice farming system under Subak management in Bali are the massive rice fields that have been converted to non-agricultural use and the irrigation water crisis.

Based on the 5 sub-indicators of human capital, only the age sub-indicator strengthens farmers' adaptive capacity, where the average age of farmers is 56 years. Meanwhile, the other 4 sub-indicators are at low levels. The age factor is related to experience in managing farming and this experience is an important adaptation capital for farmers in determining the right adaptation strategy. Financial capital also does not support farmers' adaptive capacity, as shown by low income from farming, limited development of subak economic businesses, asset ownership and low access to capital.

The socio-cultural capital indicator has the highest index value, namely 0.62. The high socio-cultural capital index is coherent with the management of irrigated rice fields with an agrarian socio-religious characteristic which originates from Tri Hita Karana as a view of life of Subak farmers. This shows that irrigated rice farming in Bali with its subak system is unique, not only as an economic activity but also as an agricultural activity with a socioreligious or sosiocultural character. These socio-cultural values are manifested by the existence of Subak temples (*pura subak*) and Subak religious rituals which are very diverse and hierarchical in nature. Subak temples and ritual activities are not just religious activities, but have an essential role in preventing social conflict, regulating planting schedules and controlling pests and diseases when facing problems of water scarcity and pest and disease attacks due to climate change [24] [10]. The results of this research confirm that the local cultural system in certain cases is an important asset that strengthens farmers' adaptive capacity.

The value of social glue in the Subak irrigated rice system is also visible from the collective action of farmers in the form of mutual cooperation and togetherness which is a manifestation of the *pawongan* component. Sriartha and I wayan Kertih [27] stated that the growth of collective action in subak was based on the principles of *paras paros sarpanaya*, and *sagilik saguluk selunglung sebayantaka*. *Paras paros sarpanaya* contains the meaning that humans must respect each other. Meanwhile, *sagilik saguluk selunglung sebayantaka* means the importance of togetherness and helping to achieve a happy and harmonious life. Awig-awig is one of the cultural capitals and social capitals that are very important to create order/ peace in subak.

Subak's physical infrastructure capital indicator has the second highest value after socio-cultural capital. The high index of this indicator is contributed by the sub-indicators of the existence and function of the traditional irrigation network, Subak Temple and Subak Office (*Bale Subak*). The physical structure of the traditional Subak irrigation network is in the form of allocation of water rights using the *tektek* system, water distribution using the *numbak* system and the existence of a one-inlet and one-outlet system in each block belonging to farmers' rice fields, has sophistication in managing irrigation water so that the available water can be used efficiently and effectively, especially in times of drought and excess water (floods) due to extreme climate change. [24] states that the tektek system is a measure of water distribution based on the principle of proportionality. One tektek (cast) of water can irrigate a rice field area of one middle bit (a rice field that requires one *tenah* seed/around 10 kg or an area of 0.30-0.35 ha) and must contribute as much as one father (one worker) and a number of contribution funds called *sarin tahun* (annual fee) are paid at the end of the harvest. This system guarantees fair and responsible water services for Subak members so that water conflicts can be avoided and supports harmonious social challenges. The *numbak* system (parallel water distribution building structure) is a water distribution that prioritizes the principles of transparency, accountability and justice. Meanwhile, the system of one tapping door (supplement) and one external door (draination) or on-inlet and one-outlet system that exists in each farmer's paddy field block has the benefit of enabling farmers to implement mutual water borrowing, carry out crop diversification and deal with excess water. (flood). Apart from that, in Subak there is a tradition of taking turns and borrowing water from each other. [28] stated that the tradition of the water lending and borrowing system provides benefits in strengthening (social) togetherness, food security, effective and efficient use of water in the face of limitations, and increasing farmers' capacity through adaptation to climate and environmental changes.

4 Conclusion

This study proves that Subak's socio-religious local wisdom values play a positive role in strengthening farmers' adaptive capacity in facing disasters such as climate change. This can be seen from the 2 local specific indicators in Subak which are used to determine farmers' adaptive capacity which have the highest index values compared to the other 3 numerical indicators.These findings also strengthen the concept that determinants and indicators of farmers' adaptive capacity are contextual and locally specific according to the characteristics of the local sociocultural, economic and geographical environment. This study recommends the importance of integrating local specific indicators and generic indicators (generally applicable) in studies of farmers' adaptive capacity.

References

[1] Ruminta. 2016. Analisis Penurunan Produksi Tanaman Padi Akibat Perubahan Iklim di Kabupaten Bandung Jawa Barat. *Jurnal Kultivasi Vol. 15(1) Maret 2016 : 37-45*.

[2] Surmaini E., Runtunuwu Eleonora., & Las Irsal. 2011. Upaya Sektor Pertanian Dalam Menghadapi Perubahan Iklim. Jurnal Litbang Pertanian, 30(1).

[3] Effendi Pasandaran, dkk. 2017. Menuju Pertanian Modern Berkelanjutan. Jakarta: IAARD Press, 2017. Viii, 431 hlm. ; 24 cm. ISBN: 978-602-344-198-3

[4] Peng, S., J. Huang, J.E. Sheelhy, R.C.Laza, R.M. Visperas, X. Zhong, G.S.Centeno, G.S. Khush, and K.G.Cassman. 2004. *Rice Yields Decline with Higher Night Temperature from Global Warming*. USA: Proc. Natl. Acad. Sci.

[5] Las, I. 2007. Menyiasati FenomenaAnomali Iklim bagi PemantapanProduksi Padi Nasional pada EraRevolusi Hijau Lestari. *Jurnal Biotek-LIPI*. Naskah Orasi PengukuhanProfesor Riset Badan LitbangPertanian, Bogor, 6 Agustus 2004.

[6] Suharyanto, dkk. 2017. Faktor-Faktor Yang Mempengaruhi Persepsi Petani Terhadap Kebijakan Perlindungan Lahan Pertanian Pangan Berkelanjutan Di Provinsi Bali. Jurnal Pengkajian dan Pengembangan Teknologi Pertanian, Vol. 20, No.2, Tahun 2017: 111-124

[7] Sudarma, I.M., & As-syakur, A.R. 2018. Dampak Perubahan Iklim Terhadap Sektor Pertanian Di Provinsi Bali. *SOCA: Jurnal Sosial Ekonomi Pertanian*.

[8] Nuryanti, L., & Waryanto, B. (2016). *Agricultural Statistics 2016*. Center for Agricultural Data and Information System Ministry of Agriculture, Republic of Indonesia. http://epublikasi.setjen.pertanian.go.id/epublikasi/tatistik%20Pertanian%202016/files/assets/co m mon/downloads/Statistik%20Pertanian%202016.pdf

[9] Mekonnen, Y.A., Kassa, K., & Ayalew, M. (2019). Prevalence, causes and consequences of divorce in Bahir Dar city, Ethiopia.

[10] Sriartha, I Putu, Sri Rum Giyarsih & I Gusti Ayu Purnamawati. (2023). Comparing the adaptive capacity of traditional irrigated rice fields farmers in urban and rural areas to climate change in Bali, Indonesia. *Cogent Social Sciences*, 9:2, 2275936. https://doi.org/10.1080/23311886.2023.2275936.

[11] Mach, K. J., Planton, S., & Stechow, C. V. (2014). *Climate Change 2014: Synthesis Report*. IPCC. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/02/ AR5_SYR_FINAL_Annexes.pdf

[12] Kusumasari, B. (2016). Climate Change and Agricultural Adaptation in Indonesia. *MIMBAR*, *32*(2), 243–253. https://doi.org/10.29313/mimbar.v32i2.1841

[13] Sumaryanto. (2013). Estimasi Kapasitas Adaptasi Petani Padi Terhadap Cekaman Lingkungan Usahatani Akibat Perubahan Iklim. *Jurnal Agro Ekonomi*, 31(2), 115–141. http://doi.org/10.21082/jae.v31n2.2013.115-141

[14] Pörtner, H.-O., Roberts, D. C., Tignor, M., Poloczanska, E. S., Mintenbeck, K., Alegría, A. … Rama, B. (2022). Food, fibre, and other ecosystem products. In *Climate change 2022: Impacts, adaptation and vulnerability. Contribution of working group II to the sixth assessment report of the Intergovernmental Panel on climate change*. IPCC. https://do.10.1017/9781.0093.25844.007
[15] Departement for International Development. (1999). *Sustainable livelihoods guidance sheets*. DFID.
[16] Defiesta, G., & Rapera, C. L. (2014). Measuring adaptive capacity of farmers to climate change and variability: Application of a Composite index to an agricultural community in the Philippines. *Journal of Environmental Science and Management*, *17*(2), 48– 62. https://doi.org/10.47125/jesam/2014_2/05
[17] Monwar, Md. Mostafa, et.al,. 2018. Indigenous Adaptation Practices for the Development of Climate Resilient Ecosystems in the Hail Haor, Bangladesh. *Glob Soc Welf (2018) 5:125–136*
[18] Kurniawan, E., Arisurya, Raditia, R. E., & Arisurya, R. E. (2020). Kerentanan dan Adaptasi Rumah Tangga Petani Terhadap Perubahan Iklim Di Kabupaten Gunungkidul. *Jurnal Agro Ekonomi*, *32*(2), 127–141. https://doi.org/10.21082/jae.v38n2.2020.127-141Kusumasari
[19] Brooks, Nick & Adger, W. & Kelly, M. 2005. The Determinants of Vulnerability and Adaptive Capacity at the National Level and the Implications for Adaptation. Global Environmental Change Part A. Global Environmental Change Part A. 151-162. 10.1016/j.gloenvcha.2004.12.006.
[20] Salampessy, Yudi L.A., Djuara P. Lubis, Istiqlal Amien, Didik Suhardjito. 2018. Menakar Kapasitas Adaptasi Perubahan Iklim Petani Padi Sawah (Kasus Kabupaten Pasuruan Jawa Timur). *Jurnal Ilmu Lingkungan , Volume 16, Issue 1 (2018) : 25-34.*
[21] Rymbai, Dayohimi and Feroze Mohammad Sheikh. 2018. The insight of agricultural adaptation to climate change: a case of rice growers in Eastern Himalaya, India. *International Journal of Biometeorology (2018) 62:1833–1845*
[22] Sriartha, I Putu. (2014). Kajian Spasial Keberlanjutan Sistem Subak Yang Berlandaskan Tri Hita Karana Di Kabupaten Badung, Bali. *Disertasi (tidak diterbitkan)*. Yogyakarta: Fakultas Geografi UGM.
[23] Nik, A., Nik, A., Zalina, Z., Siti Aida Sheikh, H., & Siti Shaliza Mohd, K. (2018). Determination of Perception and adaptive capacity towards climate change among paddy farmers in state of Kelantan, Malaysia. *International Journal of Engineering and Technology*, *7*(4.1), 118–123. https://doi.org/10.14419/ijet. v7i4.1.28238
[24] Windia, W. (2006). *Transformasi Sistem Irigasi Subak Yang Berlandaskan Konsep Tri Hita Karana*. Pustaka Bali Post.
[25] Few, R., Spear, D., Singh, C., Tebboth, M. G. L., Davies, J. E., & Thompson-Hall, M. C. (2020). Culture as a mediator of climate change adaptation: Neither static nor unidirectional. *WIREs Climate Change*, *12*(1), 1–8. https://doi.org/10.1002/wcc.687
[26] Adger, W. N., Barnett, J., Brown, K., Marshall, N., & O'Brien, K. (2013). Cultural dimensions of climate change impacts and adaptation. *Nature Climate Change*, *3*(2), 112–117. https://doi.org/10.1038/ nclimate1666
[27] Sriartha, I Putu and I Wayan Kertih.(2020). Subak Local Wisdom as Social Studies Learning Sources in Junior High Shool. Proceedings of the 4th Asian Education Symposium (AES 2019), Series: *Advances in Social Science, Education and Humanities Research, volume 438*. DOI: 10.2991/assehr.k.200513.006
[28] Sutawan, Nyoman. (2008). *Organisasi dan Manajemen Subak Di Bali.* Denpasar: Pustaka Bali Post.