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Spatial Zonation Model of Local Irrigation System Sustainability (A Case of Subak System in Bali)

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Abstract This study was aimed at designing a spatial zonation model of a subak sustainability type based on the internal and external dimentions from 69 subaks in three districts in Badung regency. The internal dimention was measured based on subak capability index in implementing Tri Hita Karana (THK) philosophy. The external dimention was measured by using index of four variables, namely: road density, population density, social economic facilities, and number of nonfarmer families.The data were analyzed using descriptive quantitative technique and spatial analysis using Geographical Information System (GIS) software. The results found three zones of subak sustainability type, spatially follows the principle of distance decay of the growth of tourism and city center. Unsustainable - less sustainable subak zone dominates short distance zone, sustainable - less sustainable subak zone dominates transitional zone, while sustainable subak zone dominates long distance zone. To protect subak from destruction, less sustainable subaks have to be restored into sustainable ones and the sustainable subaks should be made eternal/exclusive subaks.

Keywords: Spatial zonation model, Subak sustainability type

Abstrak *Penelitian ini bertujuan untuk menyusun model zonasi spasial tipe keberlanjutan subak yang didasarkan pada analisis dimensi internal dan eksternal pada 69 subak di tiga kecamatan di Kabupaten Badung. Dimensi internal diukur dengan indeks kemampuan subak menerapkan filosofi Tri Hita Karana (THK). Dimensi eksternal diukur dengan indeks 4 variabel, yaitu: kerapatan jalan, kepadatan penduduk, fasilitas sosial ekonomi, dan jumlah keluarga nonpertanian. Analisis data dilakukan dengan teknik deskriptif kuantitatif dan analisis spasial dengan software Sistem Informasi Geografi (SIG). Hasil penelitian menemukan tiga zona tipe keberlanjutan subak yang secara spasial mengikuti distance decay principle dari pusat pertumbuhan pariwisata dan kota. Zona tipe subak tidak berlanjut - kurang berlanjut mendominasi di zona dekat, zona tipe subak berlanjut - kurang berlanjut mendominasi di zona transisi, sedangkan zona tipe subak berlanjut mendominasi di zona jauh. Untuk melindungi subak dari kehancuran, maka subak kurang berlanjut agar direstorasi menjadi subak berlanjut, dan bersama subak berlanjut lainnya dijadikan subak abadi/eksklusif.*

Kata kunci: *Model zonasi spasial, Tipe keberlanjutan subak*

1. Introduction

Culture-based agriculture and tourism development is the basic potential that becomes the mainstay of Bali development. The cultural uniqueness in Balinese agricultural system is practiced by the traditional institution called subak. This means that sustainable development of Bali will be materialized if subak (agriculture) and tourism develop through a relational system that is mutually beneficial and interdependent. Tourism has to strengthen subak existence through absorption of agricultural produce and opening of agribusiness opportunity based on local culture and community. On the other hand, subak has to be capable of playing a role as a supplier, both of food products, unique agricultural souvenirs and tourist attractions.

In reality, rapid and accelerative developing tourism will threaten subak existence. Susanto (1999) and Alit Artha w., et.al., (2005) state that although Bali tourism development positively contributes to an increase in income of the people and job opportunity, on the other hand, it brings about a serious negative effect, namely a threat to subak system sustainability. Central Bureau of Statistics of Bali Province (2012) notes that in 2008 the contribution of agricultural sector in Badung Regency (one of the regencies in Bali with the highest economic growth) was 8.41%, then it dropped to 6.29% in 2012. While in the same years, tourism sector contributed 37.92% and 34.26% respectively. A study by Lorenzen (2010) notes that manpower in agricultural sector dropped drastically from 61% in 1976 to 36% in 2008. While in the same years industrial sector manpower (including tourism) increased from 12% to 24%. Sutawan (2005) and Windia (2008) state that almost all subaks in Bali are experiencing a marginalization process that ends up with unsustainability. A foreign

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scholar named Lansing (Sinar Harapan, 2013) has studied subak since 1974 and also sees that currently subaks in Bali are in the verge of destruction because of its popularity.

The form of threat to subak sustainability is also present in the disturbance to the *Tri Hita Karana* (THK) components that is the philosophy or guidance for subak life. The THK teaching in subak stresses on the importance of a harmonious life and solidarity to achieve welfare among its members. The THK teaching consists of three components that have to be made harmonious: *parhyangan* (relationship between human being and God), *pawongan* (directing the relationship among a human being and other human beings) and *palemahan* (directing the relationship between human beings and the nature). The THK component that is seriously threatened is *palemahan* component, in its massive forms are exemplified by land conversion and scare irrigation water, and *pawongan* component as exemplified by the change of occupation from farmers to jobs in tourism industry and the fading away of collective life (mutual cooperation and subak meeting).

This study was aimed at developing a spatial zonation model of subak system sustainability that is based on subak internal and external dimensions. The internal dimension was focused on the implementation of subak THK philosophy, while the external dimension was analyzed from the variables of tourism and urban development, namely urbanization (population density), road network, the proportion of nonfarmer population, social economic facilities available in the subak area. The zonation model resulted is expected to become one of the spatial solutions to determine subak areas that can and cannot be developed into sites of industries (urban and tourism development), at the same time as a "win-win " solution to materialize a mutual synergy between agriculture (subak) and tourism (urban development).

The sustainable development concept has a wide variety of meanings, such as seen in the formulation put forward by WCED (1987 in Lee, 1999; Cai, et. Al, 2001), that is a development that guarantees the current needs of the people without reducing the rights of the coming generations in meeting their life necessities. This definition implies that a sustainable development is always related to the management of resources whose function and use remain preserved for today's and tomorrow's generations. The function and use of the irrigation system have to be socially, economically, culturally, technologically and environmentally holistic.

The sustainability of the irrigation system is affected by internal and external factors. Liu, et.al. (2001) state that the sustainability of an irrigation water source system has the same meaning as resilience which forms a function of the intrinsic capability (reflected from the capability of adaptation) and external stress value (disturbance from nature and human). The internal factor is related to the ability of the people to manage the irrigation system. Arif (2003) states that internally the irrigation system is a socio-cultural system of the community that consists of four subsystems, namely mindset subsystem, socioeconomic subsystem, artefact (including technology), and nonhuman subsystem.

Subak system as a local irrigation institution that was born from the Balinese agricultural culture has an internal strength or local genius called *Tri Hita Karana* (THK) philosophy. The THK philosophy is the guidance for Balinese life that originates from Hinduism. *Tri* means three, *Hita*, happiness/welfare, and *Karana,* cause. *Tri Hita Karana* means the roads to happiness, namely, *parhyangan* (creating a harmonious relationship with God), *pawongan* (creating a harmonious relataionship with other fellow humanbeings), and *palemahan* (creating a harmonious relationship with nature). The *parhyangan* component is the realization of the cultural wisdom, the *pawongan* component is the realization of the social and economic wisdom and the *palemahan* component is the realization of the technological and ecological wisdom (Sriartha, 2014).

Based on the THK philosophy, subak is very unique and has a variety of advantages, among others as the most effective and sophisticated water irrigation institution in the world (Ostrom, 1992; Amber, 1992), preservation of ecosystem, social economic life unifier, culture supporter and food self sufficiency (Lansing, 1987; Kasryono, et. al, 2003; Baharsyah, 2005; Sutawan, 2005; Lorenzen, 2010; Lansing and Therese A. de Vet, 2012). Then, United Nation through a UNESCO assembly on June 29, 2012 decided subak to be a world heritage because it has extraordinary authentic values and universal values, including a very strong social cohesive value (ANTARA, 2012). Hence, it can be stated that THK is an internal strength that forms the sustainability source of the subak system.The sustainability of an irrigation system (like subak) is also affected by the dynamics of its external environment. According to Abernethy (1991) and Shady (1991), the external environment that can threaten the irrigation system sustainability consists of the dynamics of the physical, social, economic and cultural, financial, ecological environments and the government authority policies. Sutawan (2005), and Drydale and K. Zimmerman (1995) state that globalization, industrialization, advances in science and technology, and green revolution have negative effect on agricultural, environmental conservation and local genius sustainability in a region. Bataskoti, et. al. (2010) that studied local irrigation systems in Nepal and Thailand, found that market economic development (agricultural commercialization) and the government policies have an effect on local irrigation performance, in the form of decrease in farmer collective life, reduction of capital invested in agriculture, and the shift of farmers to other sectors with a higher income. In relation to the effect of the regional development in the form of tourism development, Susanto (1999, 2000) and Alit

Artha, et. al. (2006) found that tourism development as part of the regional economic development has a positive and negative effects on subak. Despite of the presence of positive effects, both scholars conclude that the increasingly rapid tourism development becomes a serious threat to subak sustainability in Bali, especially in the subak area close to a tourism center with a heterogeneous population and a numerous social economic facilities.

A model can be defined as a representation of a reality made by the model maker. In other words, it is a connecting medium between the real world and conception done with the aim of solving a problem. Hence, a model is a simplification of the reality (Marfai, 2011). In this study, the model intended is a spatial model shown in the form of a map and diagram that describes subak system sustainability zone types. The model developed was based on the interdependence among three variables: geographical location, subak THK implementation, and external threat.

Zonation is a technique to divide the region based on function, condition and potential to decide an appropriate, effective and efficient management (Muta'Ali, 2013). Zonation is basically a process of classifying certain criteria to produce a pattern of space uses. Space use zonation theory was introduced for the first time by Von Thunen (1826, in Daldjoeni, 1992) called concentric theory of agricultural land use pattern. According to Van Thunen, agricultural land use system forms a concentric pattern with the highest level of benefit in accordance with the relative location (distance) from the market town. The distance factor will determine choices of the nature of produce of plant types, production cost (manpower) and transportation cost. The nature of easily perishable crops needs plenty of workers, and the transportation cost is high. They tend to be cultivated in a location that is the closest to the city center. Furthermore, Alonso (1964) introduces bid-rent theory and Clark (1982) introduces trade-off theory about land use pattern. The two scholars state that land use spatial pattern forms a concentric pattern with certain functions in each zone since it is determined by the land value/ lease with distance decay nature from the center of the city. The farther the land is from the city center the lower its lease/value will be.

2. The Methods

This study was conducted in the central part of South Bali, in three districts in Badung Regency (Mengwi, Kuta Utara and Kuta Districts). The research area was selected since it is a productive wet land agricultural zone, the metropolitan zone as well as the tourism center that develops rapidly. This area is also experiencing the highest economic growth compared to other regencies and cities in Bali with the consequence of having the very dynamic land use.

The unit of analysis was subak region with the total of 69 subaks, consisting of 47 subaks in Mengwi District, 19 in Kuta Utara District and 3 in Kuta District. The measurement of subak sustainability was computed by combination technique which combines the relative index score of the variables of the implementation of THK philosophy and the external threat. The data about the implementation of THK philosophy consisted of cultural, social, economic, technological, and natural physic subvariables collected from *pekaseh* (leaders) of each subak using group interview and the data units were in the form of scores.

The data about the external variable consisted of road density, population density, percentage non-farmer families, social economic fasilities with subak geographical location as control variable. Subak geographical location was measured by the geometric distance of the subak area to Kuta tourism center and analyzed by the multiple ring buffer model of SIG. The data about road density was expressed by the sum of the lengths of roads of all types divided by the area of subak region, computed by the polygon buffer model of SIG. The data source about distance and road density was the 2009 land use map. The data about population density were computed by the size of population divided by the area of subak region shown in the population/ hectare unit. The data about the percentage of nonagricultural households showed the proportion between the total number of nonagricultural households and the total number of households in the subak area. The data about the presence of social economic facilities consisted of the sum of 19 weighed social facilities and 17 weighed economic facilities in the subak area. The data about population density, percentage of nonagricultural households and social economic facilities were taken from Central Bureau of Statistics, Badung Regency.

The data were analyzed using descriptive quantitative technique and spatial analysis (using GIS software). In the descriptive quantitative analysis, the data about the implementation of THK and the data about the external threat were quantitative data shown by index, after that classification and evaluation criteria were established, then the data were analyzed using narrative-interpretative technique supplemented by cross tabulation, mean score, and percentage. The computation of the indexes was done as follows.

VI = (value obtained–the lowest value)/
(the highest value-the lowest value) x 100…..(1)

VI = Variable/Sub Variable Index

The index of the implementation of THK was computed from the total score of the implementation of the THK components namely *parhyangan* (culture), *pawongan* (social and economic), *palemahan* (technology and natural physical). The index of the external threat was of mean score of population density, road density, percentage of nonfarmer households and social economic facility indexes. The multitude of the

Table 1. Criteria of Scoring for the Implementation of THK and The External Threat

Index Classification	Criteria of The Level of Scoring for The Implementation of THK	Criteria of The Level of Scoring for The External Threat
0 - 33	Low	Low
34 - 66	Medium	Medium
67 - 100	High	High

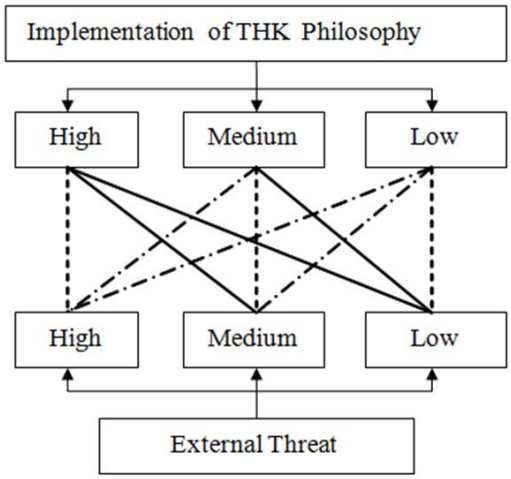

Figure 1. Combination technique for scoring subak sustainability type

Note:

Sustainable Subak Type
Less Sustainable Subak Type
Unsustainable Subak Type

score of index resulted ranged from 0 to 100. Based on this range of the score of index the following criteria of scoring was determined (Table 1).

Based on the criteria in Table 1, the status of the type of the sustainability of each subak would be determined by using combination technique that combines the level of the implementation of THK and the level of the external threat. It was postulated that the higher the implementation of THK and the lower the external threat, the higher the subak sustainability, and the reverse. The guideline for the combination technique is as shown in Figure 1.

The spatial analysis of subak sustainability type was based on the map of subak sustainability types. In the map, the geographical locations of subak were grouped into three based on their geometric disctance from the tourism center, namely short distance zone (index 0 – 33), transitional zone (index 34 – 66) and long distance zone (index 67 – 100). Subak type sustainability spatial pattern was determined by observing the distribution of each zone. The design of spatial model of subak sustainability type was based on the simplification of the map and the interdependence between the variables of the implementation of THK, external threat and subak geographical location.

3. Result and Discussion

The result of this research showed that every subak system has a different capability in implementing THK philosophy. There are 31 subaks (44.93%) that belong to good subaks in THK implementation, those threat belong to medium subaks are 26 subaks (37.68%), and the bad subaks low in THK implementation are 12 subaks (17.39%). The implementation of *parhyangan* component (culture) has the highest ranking (index = 64.87), followed by *palemahan* component (technical and natural physical domain) with the index 57.96 and the lowest is *pawongan* (social and economical domain) with the index 47.07.

The high score of cultural domain implementation proves that subak as an irrigation institution with its religious nature in which there is a religious a reasonably strong cohesion among its members. The strength is reflected by (1) the still strong belief among its members/ *krama* in the mighty God as the creator of water and land fertility with its rice plants. God created water which is symbolized in God *Wisnu*, and God created land fertility which is symbolized in Goddess *Sri*. This belief is seen in the allocation of fund made to implement the religious ritual activity and build a huge subak temple. The information gathered from the

pekaseh shows that more than 50% of the subak finance is allocated to build a temple and to hold the religious ritual. (2) there are a numerous types of religious ritual activity in a subak, from the land preparation ritual to a ritual in the granary (*jineng*). (3) the preservation of subak temples which are hierarchically structured starting from the lowest level in each door to farmer's rice field water block (*Sanggah Catu*) to the highest in the form of Pura Ulun Danu.

The economic domain is the major factor affecting the weak capability of the subak to implement THK. The result shows that all subaks face the economic problem as indicated by the weak capability to develop a mutual economic enterprise, the increase in the operation and maintenance cost of the subak facilities and the low income earned from farming. The weak economy becomes the source of problems in other aspects shown by (1) the weakness in *awig-awig* (rule in use) implementation, (2) the less participation of the members in collective activities, (3) increase in competition over water use with other parties, and (5) the rate of land conversion from rice field to non-farming use that is uncontrollable.

The external threat to subak sustainability was analyzed from the mean score of four external factor indexes, namely land density, availability of social economic facilities, population density, and percentage of non-farmer households. This was based on the understanding that the four factors represent growth in the development in secondary and tertiary sectors, such as tourism industry and urban development that cause agricultural area (subak) transformation.

The result showed that 12 subaks (17.39%) experience a high level of external threat, 26 subaks (37.68%), medium level of external threat and 31 subaks (44.93%), a low level of external threat. The external factors that trigger the increase in subak external threat is the growth in road networks. This can be understood since the growth in road networks will increase the region accessibility. Muta'ali (2013) states that transportation factor is one of the major motifs in the development of a region, the region structure formation, and the determinant of the spatial orientation and connectivity of the region. A high region accessibility will motivate the stakeholders to live and open various social economic activities in the region that land use system, economic structure and demography that were initially agriculturally dominant become more heterogeneous (the increase in nonfarmer population, the increase in population density and social economic facilities). Susanto (1999) and Mac Rae and I.W.A. Arthawiguna (2011) state that the heterogeneity of cultural, social, economic and physical life is not suitable for the existence of the subak as a homogeneous wet land irrigation community that originates from Bali Hindu culture.

Based on the criteria in Table 1 and Figure 1, the analysis of the data about the index of THK implementation and the index of the external threat showed that 39 subaks (56.52%) belong to the sustainable type, 18 subaks (26.09%) to less sustainable subak type and 12 subaks (17.39%) to unsustainable type. Spatially, unsustainable – less sustainable subak types dominate in short distance zone, sustainable-less sustainable subak types dominate in transitional zone, while sustainable subak type dominates in long distance zone (Figure 2). The formation of such pattern is the result of the effect of the internal factor (THK implementation) and the external threat factor that are different in each zone. The interaction pattern of the two factors in each zone is shown in Figure 3.

The result in Figures 2 and 3 shows that unsustainable subak is characterized by the decreasing level of THK implementation parallel to the increase in the external threat and the closer distance from the subak region to the tourism center. While sustainable subak is characterized by the increasing level of THK implementation level parallel to the decreasing level of the external threat and the farther distance from the subak region to the tourism center. The characteristic of less sustainable subak is that it is situated between sustainable subak and less sustainable subak. Based on the result, we can design a spatial model of subak sustainability types as shown in Figure 4.

If we look at Figure 4 closely, we can see that the zonation model of spatial subak sustainability types consist of three zones, namely short distance zone which is unsustainable – less sustainable subak type, transitional zone which is sustainable- less sustainable subak type and long distance zone, which is sustainable subak type. This fact occurs because of the development of tourism and subak internal capability that follow the principle of distance decay, in which the farther it is from the tourism center the lower is the external threat will be while the THK implementation will be higher , and the reverse.

The finding of this zonation model of subak sustainability has something in common with farm land use pattern from Von Thunen's model (1826), The difference is only in (1) the criteria used in designing the model which are based on the strength of the external effect, THK endurance, and distance from subak region to the tourism center. While Von Thunen used the principle of the level of agricultural crop advantage level based on the nature of the crop, production cost, and transportation cost (distance). (2) the focus of the model is zonation of spatial types of traditional irrigation system (subak) sustainability types, while Von Thunen focused on zonation pattern of agricultural (crop) land use types. The model produced in this study also corresponds to bid-rent model from Alonso (1964), trade-off model from Clark (1982) about patterns of land use, and landuse triangle continum theory from Yunus (2008) that clasifies peri urban area into four zone (urban, urban-rural, rural-urban, and rural frame zones) by using the criteria of

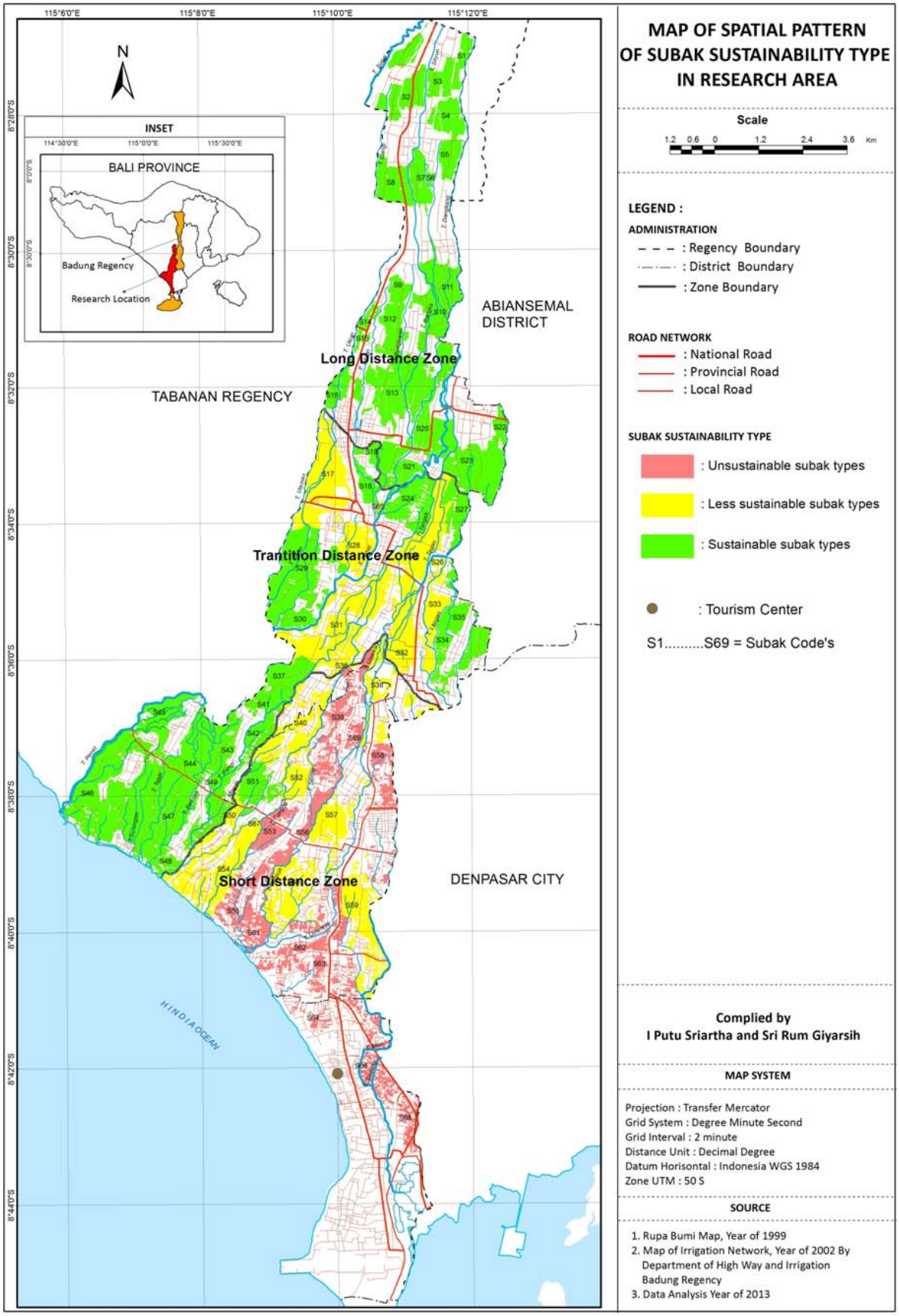

Figure 2. Spatial pattern of subak sustainability type

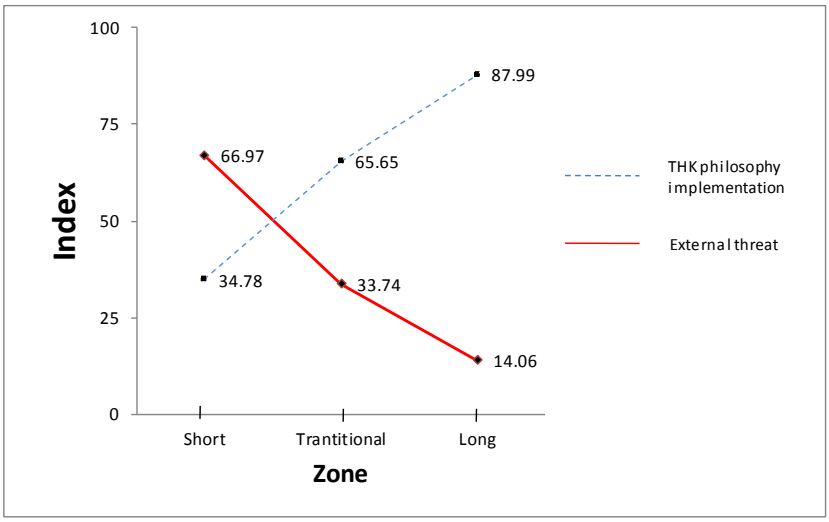

Figure 3. Interaction pattern of THK implementation and external threat in each zone

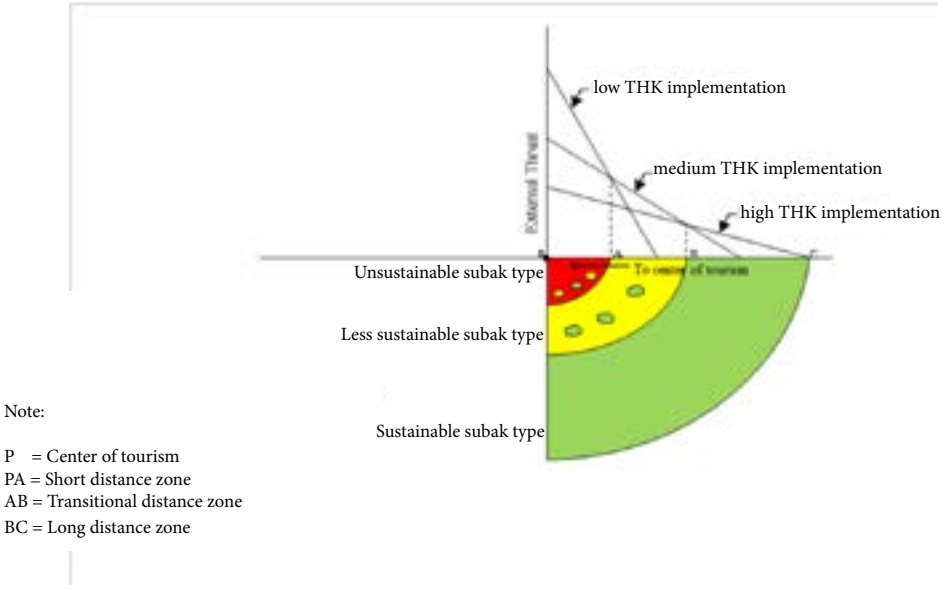

Figure 4. Spatial zonation model of subak sustainability type

distance to urban center, percentage of urban landuse, and percentage of rural landuse.

4. Conclusion

Subak system sustainability is determined by three interrelated factors: internal, external and geographical location. The internal factor is the capability of the subak members and leader in implementing THK philosophy. The good category subaks whose THK implementation is high are 31 in number (44.93%), the medium ones are 26 subaks (37.68%), and the bad ones are 12 subaks (17.39%). The implementation of *parhyangan* (culture) component ranks the highest (index = 64.87), followed by *palemahan* component (technical and natural physical domain) with the index 57.96 and the lowest is the *pawongan* component (social and economic domain) with the index 47.07. The external factor is embodied in the growth of tourism development represented in the form of road networks development, population density, social economic facilities, and percentage of nonfarmer households. The four external factors form the source of threat to subak sustainability. It is noted that there are 12 subaks (17.39%) experience a high external threat, 26 subaks (37.68%), a medium external threat, and 31 subaks (44.93%) , a low external threat. The triggering factor of the increase in subak external threat is the development of road networks. This can be understood since the development of road networks increases accessibility to the region. The geographical location factor is embodied in the distance from subak region to the tourism center. In the short distance zone, subaks experience the highest external threat and the

lowest THK implementation, while in the long distance zone subaks experience the lowest external threat and the highest THK implementation.

The relationship among the external factors, the internal factors and the geographical location produces a typical zonation model of subak sustainability types. The short distance zone is the zone dominated by unsustainable – less sustainable subak types. The transitional zone is the zone dominated by sustainable-less sustainable subak types, while the long distance zone is dominated by sustainable subak types. This model is formed from the result of interaction among the external threat and subak internal capability that follows the principle of distance decay, in which the farther it is from the tourism center the lower is the external threat while the THK implementation capability will become higher, and the reverse.

To protect subaks from destruction, it is suggested to the local government as the authority in making development policies to change the current development policies (massive tourism with high capital bias) into participative development policies based on agriculture and culture that synergize with tourism. The action programs that need to be executed are (1) drafting the local regulations about eternal/exclusive agriculture (subak) region, (2) subak economic empowerment program through agro-eco-businesses based on THK, for example, the development of agro-tourism, ecotourism, tourism village, integrated organic farming, etc, (3) subsidy programs in agriculture produce and insurance, (4) financial grant program, and (5) subak institution strengthening program.

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