Sustaining *subak*, the balinese traditional ecological knowledge in the contemporary context of Bali

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Abstract. Subak is a local organization that formalizes the Balinese traditional ecological knowledge and wisdom in managing and distributing water for agricultural purposes. This organization combines cosmology, spirituality, science, ecology, and engineering dimensions of knowledge. As the current development of Bali Island as one of the international tourist destinations has changed its landscape which involves various factors such as physical, social, and cultural. Hence, to what extent the traditional ecological knowledge (TEK) practice can be sustained in the current context and development setting become our focus of study. This paper has three objectives. The first is to collate/document the various perspectives of TEK from sustainable agriculture practices, ecological principles, water irrigation systems, and spiritual practices and values as part of the learning document. The second is to analyze the interdependence of the human and environmental systems in the context of the socio-ecological system framework for Subak TEK and its cultural sustainability. Third, to outline the potential effort to sustain Subak TEK by strengthening its adaptive capacity in the broader context of learning to strengthening the community based tourism planning. This study deploy the socioecological system, SES framework as the underlying theory and analysis and explore diverse initiatives to sustain Subak in the future. The study was conducted in conjunction with a sustainability leadership program which deployed an inter- and transdisciplinary approach of sustainability science that focuses on Subak as its case. Situational and content analysis from the workshop discussion notes is used to provide examples that describe diverse initiatives in tourism, agriculture, and education. The study found out that the SES framework of analysis in Subak TEK documented several core ritual activities, the interpretation of THK philosophy and its local wisdom and values which represent the interaction the social and natural system. Hence, demonstrate as a living monument with strong human institutions and nature interaction. Further, the Subak TEK has substantial community capital values that need to be strengthened by integration in the formal and non-formal education, the enhancement of the Tri Hita Karana (THK) awards and accreditation for tourism operators and hotels in the broader context of education for sustainable development framework as well as community-based tourism development planning. This initiative need to be supported by a community-based tourism by involving Pekaseh and youngsters in the current context of Bali community-based tourism. **Keywords**: Ecological, sustainability, tourism, planning, education

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1. Introduction

As Bali is famous as one of the beautiful islands with its unique cultural activities and has been attracting massive tourism activities, the tourism development affects the society's life structure. Decreasing land for agriculture, as the basic core culture of the *Subak, will* threaten the existence of Balinese culture and traditional practice or known as 'acculturation' [1]. For example, agricultural values and technological changes led to the economic field [2] and shifted from an agriculture-based society to a tourism service industry [3]. This transformational process would lead to the modernization and development of the Balinese people who are rich in cultural traditions and heritage. An effort to protect these cultural values and traditions in the establishment of a world heritage site cultural landscape is one way to protect and preserve this culture, tradition, and heritage in the context of the socio-ecological system, SES.

Deployment of the SES framework to analyze Subak is closely associated with humans and its ecological system. Subak, as a traditional water irrigation system for Balinese, also known as a religious and social organization for rice cultivation, has been recognized as part of the world heritage status of UNESCO since 2012. Its formal name, *Bali province Cultural Landscape: Subak system as a manifestation of Tri Hita Karana philosophy* manifests the Balinese outstanding universal value, OUV. It is stated that "The *Subaks* and water temple networks of Bali reflect the Balinese philosophical principal Tri Hita Karana ("Three causes of goodness"), which promotes a *harmonious relationship* between the individual and the *realms of the spirit* (*parahyangan*), *the human world* (*pawongan*) and *nature* (*palemahan*). The philosophy has manifested in various activities of the daily life of the Balinese people and its rituals, which reflect the universal values which are significant in the current context of sustainable development. The gazettement of the rice terraces, water temple network, and Subak water irrigation system were recognized under the four criteria of outstanding universal value; (i) the existence of Subak institutions, (ii) the Subak system that applies the concept of Tri Hita Karana (THK), and (iii) the landscape that is present in Bali in the form of Subak rice fields is a landscape containing a charge of cultural activity. These criteria exhibit an outstanding example of a traditional human settlement or land-use representative of a culture (or cultures) (iv) and associated with events or living traditions, ideas or beliefs, or artistic and literary works of outstanding universal significance. Hence, Subak carries the traditional ecological knowledge, TEK, which contain the physical, natural, and cultural aspect of human interaction with the environment which is valuable for future physical and tourism planning of this area.

In the current context of development and to keep up with tourism industry demand which requires physical development, there is a decrease in rice area in Bali each year on average about 1000 hectares (the year 1985 to 1989), a decrease of 4,000 hectares per year since 1994, and reached 5,000 hectares/year in 2000 [4]. Of the total Bali Island area (563.286 ha), about 17% or 97,337 ha are rice fields [5]. The data shows that the agriculture sector has become less competitive than other economic activities in Bali. Knowing that the Subak system requires agricultural land and water irrigation, this statistic threatens its existence in the current contemporary context of Bali.

This article will extend the argument of sustaining Subak through education as described in previous literature [7]. Furthermore, we argue that there is a need to sustain Subak as a TEK through education based on an identity perspective in a broader learning context of education for sustainable development, ESD. This process will need to consider one of the TEK aspects described by Houde [8] as culture and identity. Through the educational process, SUBAK as TEK also provides a 'vector' for Balinese identity that considers local stories, values, and social relations that reside within this system. The identity perspective used in the learning process about Subak will support community members to acknowledge and explore Subak as part of their cultural heritage as Balinese. While narrative pedagogy applied in learning about Subak will support TEK contextualization that will consider the current social, historical,

and cultural context. Houde describes that place as a site for stories, values, and social relations that contribute to the 'survival, reproduction and evolution' of culture and identity [8]. Hence, Subak will be part of the education process in Bali that is not only attending to the historical and cultural roots. Furthermore, when narratives about Subak are framed with emotional and moral logic, the process might engage future Balinese to overcome internal and external barriers to engagement in finding alternatives and innovations to sustain Subak in the future. This educational knowledge values has essential element for cultural sustainability and the tourism planning of this area.

This paper aims to collate/document various perspectives of TEK from various epistemology of knowledge, i.e., the sustainable agriculture practices, ecological principles, water irrigation system, and spiritual practices and values as part of the learning document. This is further to have a better understanding of human and environmental systems in the context of the socio-ecological system of Subak TEK; Third, to outline the potential effort to sustain Subak TEK by strengthening its adaptive capacity, which includes the cultural community-based tourism within the broader context of ESD and tourism planning . The study will then outline the potential strategic recommendation to sustain Subak in Bali's current context of development.

2. Literature Review

The interdependence between the human system and the environment is best explained by socialecological systems (SES). The understanding of the structure and function of systems, as well as their resilience, improves their adaptive potential in nature [8,9,10]. The system established by the ecological awareness of the people who live and use the resources of a place helps illustrate the value of traditional and context-based knowledge as well as social capital of the Balinese people. Understanding the connectivity aids in the integration of various natural scientific and social science perspectives specify in the context of development planning of the area. The system established by the ecological awareness of the people who live and use the resources of a place helps illustrate the value of traditional and context-based knowledge. This picture demonstrates why Subak TEK should be sustained.

Subak is not only a human organisation that manages the irrigation system while keeping ecological function and natural resource efficiency in mind, but it also has spiritual values. In practise, Subak as an irrigation system is a bounded socio-cultural system of the local community, based on an understanding of the underlying principle of Tri Hita Karana, which is integrated into the physical buildings and the water temple network, which represent a complex of Subak TEK in the context of the socio-ecological system. This is where the water is distributed and coordinated in an institutional manner by the Pekaseh (Subak chairman), which has become the basic socio-cultural of the Balinese people. It is a component of a complex system that manifests as numerous rituals, morals, legal systems, behavioural patterns, arts, customs, social organisations, and belief systems to assist humans in maintaining their societal lives.

TEK may be defined as "*a cumulative body of knowledge, practice, and belief, evoked by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with the environment... [TEK] is both cumulative and dynamic, building on experience and adapting to changes*." [11]. TEK has the potential to contribute by providing a basis for resource management planning and other development planning, which was recognised in the Brundtland Commission, the Convention on Biological Diversity, the Forest Principles, and Agenda 21 in the early 1970s. Implementation of TEK by the Balinese people demonstrates the practise of education for sustainable development, ESD, which manifests life-long learning practises of non-formal education and experiential learning in empowering a community to take care of the environment through Subak and its customs and traditional values.

Education for Sustainable Development (ESD) empowers learners of all ages with the knowledge, skills, values, and attitudes to address the interconnected global challenges we are facing, including

climate change, environmental degradation, loss of biodiversity, poverty, and inequality [12]. According to this definition, learning must prepare students and learners of all ages to find solutions to the challenges of today and the future. Hence, education should be transformative and allow us to make informed decisions and take individual and collective action to change our society and care for the planet. This paper will find ways to sustain Subak in the context of Bali's current challenge as a tourist destination. In this paper, we shift the focus from the analysis of trends in specific bodies of TEK to the analysis of the factors and conditions that maintain or undermine people's ability to adapt and regenerate TEK in the face of changing environmental and socio-economic conditions as well as for future planning of this area. In doing so, we advance our understanding of how factors underlying the loss of TEK affect the mechanisms used by societies to regenerate and transmit such knowledge in the face of global environmental change. Merging traditional knowledge, practices, and beliefs will create novel forms of knowledge and technologies for the creation of new knowledge systems [13]. It is part of the experiential knowledge that provides important insights for the design of adaptation and mitigation strategies for tourism and physical planning and development. Hence, it may help to promote the maintenance and restoration of living TEK systems as sources of social-ecological resilience.

2.1 Subak as traditional ecological knowledge

As non-formal knowledge, Subak has a unique value and traditional ecological wisdom. It has been maintaining, conserving and developing for a long historical interaction with its environment or codependency that manifests in various ways in safeguarding the environment and becoming a foundation for decision makers at the local level in various aspects of daily life, such as hunting, fishing, catching food, farming, livestock raising, conservation and management of food security. Such wisdom has been scanned through generations by using the traditional educational forms such as ritual, duplication, memorization, village meetings, folklore, taboo, and myth [14]. This traditional wisdom has multiple functions; one of them is in managing food security and biodiversity, such as plant classification, biological pest control, plant breeding, and environmental conservation. Ethnoscience contributes to the development of modern science in many ways, such as the agricultural system of intercropping [15], domestication technique, and plant classification system [16]. Ethnoscience contribution in the modern science reflect their ability to contribute to science and technology.

The traditional ecological knowledge, TEK, describes the ecogical principles, engineering, and the social and spiritual dimensions of cultivating rice. Subak gained local knowledge for sustainable resource management, which included planting rice, pest control [17], integrated rice-fish culture [18] and building the irrigation systems. Hence, it represents the environmental system to facilitate the human agricultural system. In this study, Subak provides tacit knowledge to plant rice and an understanding of the local knowledge that enables sustainable human development of Bali's steep volcanic slopes. This is coupled with the Balinese traditional organisations in managing and distributing water for agricultural purposes, which reflect a complex adaptive system and governance [19] and provide a testing ground for TEK. TEK Subak includes the sustainable resource management system reflected in the ecological cultural landscape of rice terraces with the cultural aspect of sixteen ritual ceremonies and involves the organisation of Pekasih, or head of farmers, to take care of the Subak. This organisation reflects the institutional frameworks and social networks that have been tested over the years [9]. Subak is also an example of 'third space knowledge', which is defined by Turnbull [20] as knowledge produced locally and socially through activity that links "people, skills, local knowledge, and equipment through social strategies and technical devices". He further argues that the social methods used to produce, transmit, and utilise knowledge require an essential component of "social organisation of trust." In Subak, this social organisation of trust is achieved through spiritual and social practises performed in the communities. However, the current context of Bali tourism may change the way we sustain the Subak TEK. Hence, exploring the social-natural interaction is crucial for the sustainability of TEK.

The United Nations Convention on Biological Diversity, UNCBD defined TEK as the knowledge, innovations and practices of indigenous and local communities around the world. Developed from experience gained over the centuries and adapted to the local culture and environment, traditional knowledge is transmitted orally from generation to generation. It tends to be collectively owned and takes the form of stories, songs, folklore, proverbs, cultural values, beliefs, rituals, community laws, local language, and agricultural practices, including the development of plant species and animal breeds. Changing in the society practice implies the changing of TEK being produced and utilised by the society which is closely related to their SES. Therefore, the resilience of SES is influenced by social factors, such as people's ability to anticipate changes and plan for the future (i.e., adaptive capacity) [21].

There are several study highlighting the role of TEK that links to social mechanisms and it's role in supporting sustainable ecosystem management and resource planning. Acquire knowledge of complex systems as an ongoing, dynamic learning process that emerges from the people's institutions and organizations involved in the process to sustain the TEK [22]. This process requires effort for continuous testing, learning about, and developing knowledge to cope with change and uncertainty in complex adaptive systems. For example, Acequias, traditional culture of water irrigation system in arid landscape of the southwestern United States and northern Mexico [23], the Persian Khettara or qanat function as subsurface irrigation channels [24], the traditional mountain irrigation covers design principles, governance, and organization and water management strategies called Bisses from Switzerland [25] and Falaj as a canal system to collect underground water in Oman [26]. The problem of adequate protection for these resources stems from habitat loss and lack of adequate information on how biotic resources were sustained through TEK in the past [27]. However, the research identifying TEK as a potential source of knowledge development and advancement and its application to further improve the adaptive capacity of the local people in the future is limited.

The ability of TEK to adopt external and internal changes tests the adaptive capacity of human ecology [19]. Loss of TEK capture in the current education system and technology due to its inability to integrate into the market economy affects its resilience and its capacity to evolve [28]. The ability of the school system to accommodate market-related activities in their environmental and cultural context is less known. In other words, our ability to understand the process, what the current situation of TEK is, the practises in society, and the capacity of society to evolve and adapt is still limited. The importance of contextual social transmission of knowledge is highlighted in a study by Reyes-Garcia et al. [29]. At this point, it might also be useful to take into consideration the perspective of knowledge is "dynamic, plural, and heterogeneous". Hence, TEK might be included in the local curriculum as specific knowledge that is useful for the Balinese context.

2.2 Subak as community-based tourism opportunities

Tourism is the largest economic sector in Bali that provides job opportunities for the majority of the local communities, including transportation, accommodation, food and beverage, cultural entertainment, and shopping sectors. Most of these sectors' participation are local-oriented including the low-income people in both rural and town areas. Community based tourism (CBT) has proven to offer various benefits and contributions the local communities of host destinations [30, 31] and as part of the initiatives for a community development to a nation direction [32, 33] which strengthening the local economy in many countries across various communities and its resources.

To date, when a tourism destination has not been properly organized [33]), leads to the environment management is poorly structured [34], pollution, degradation of biodiversity [35], degradation of cultural resources [36], low skilled and low paying employment [37] and changed the locals traditional livelihood [38]. Here, Subak is placed on the local benefits solutions. Its unique attraction provides sustainability, social equity, and environmental responsibility. Linking the community role in Bali with natural and social engagement, Subak is managed and protected by the local communities while allowing tourists to increase their awareness and learn about local lifestyle. This is also a potential

initiative for natural dependent communities in Bali through the proper management and protection of cultural resources. Subak should be considered as one sector type of tourism that offers a range of activities and other attractions, such as homestay and local owned lodge, community tour guides, local restaurant. Hence, strengthening Subak TEK function as a social capital for community-based tourism planning and its physical infrastructure development.

3. Methodology

This study deployed situational analysis to identify and facilitate the description of social processes in the current context of Balinese Subak TEK [39]. "This study also uses content analysis to systematically analyse written, verbal, or visual documentation used qualitatively or quantitatively. The content analysis includes conceptual and relational analysis. Content analysis is a highly adaptable research method that has been widely used in the study of library and information science (LIS) to achieve a variety of research goals and objectives [40, 41, 42] The content analysis conducted in this article is a systematic and rigorous approach to analysing documents obtained or generated during research.

This is supported by document analysis for TEK Subak to describe its details related to the Subak water temple network, socio-cultural values and its ecological function, sustainable agricultural practices, and the spiritual aspect of Subak. This research also deployed a socio-ecological system (SES) framework to analyse the TEK aspect. The integrative function of SES, which is shown in a bio-geophysical unit that could explain its associated social actors and institutions. SES helps to explain the complex and adaptive approach delimited by spatial or functional boundaries surrounding particular ecosystems and their context problems. This is to explain the complexity of Balinese socio-cultural tradition with Subak and the interdependence of ecological knowledge of Subak and the Balinese people in the past and current situation. Therefore, Balinese people's TEK norms, values, and cultural traditions will relate to environmental science and social science knowledge. The SES framework is widely regarded as the most comprehensive conceptual framework for analysing interactions and outcomes [43, 44, 45]. The SES is truly interconnected and co-evolving across spatial and temporal scales, with the ecological component supplying essential social services such as food, fiber, energy, and drinking water. As a result, SES has emerged as a new focus in scientific and policy circles. Also, SES research is interdisciplinary in nature, focusing on not only understanding many aspects of system functioning but also on the development and implementation of normative societal goals, such as those related to sustainability.

The study is also part of the AKEPT Sustainability Leadership Program 2017, funded by the Academy Leadership of Higher Education Institution, Ministry of Higher Education, Malaysia. Several visits to several Subaks and rice terraces have been made during the program. Several in-depth interviews were conducted with local tour operators, and several Pekaseh were identified as key informants during the programme preparation and execution. We collected data through semi-structured interviews, which provide greater flexibility for collecting a variety of information and allow interviewers to gain a deeper understanding than structured questionnaires, and through additional participants based on recommendations from those who have previously been interviewed. Furthermore, the interview results are narrated to be contextualised in historical, social, and cultural contexts.

4. Results

This study documented several aspects of Subak TEK, covering the traditional water irrigation system and its water temple network, the socio-cultural values and its ecological function, and the spiritual aspects of TEK Subak.

4.1 Subak water temple network, the socio-cultural values, and its ecological function

The Subak system has unique characteristics where farmers specifically build a temple called Pura Ulun Carik or Pura Bedugul to worship God. This pretentious existence is an expression of gratitude and

gratitude to the farmers who intended to worship Dewi Sri as a manifestation of God as the goddess of prosperity and fertility. Bali's Subak are rooted in four lakes: Batur Lake, Beratan Lake, Buyan Lake, and Tamblingan Lake. located at the highest location of the temple network of Subak due to its geography. The water from Ulun Danu Water Temple spreads downstream, becoming a complex of the temple network. Ulun Batur Lake Temple coordinates a temple network for more than 200 Subak, which covers the six divisions in Bali. The arrangement covers ritual activities and also the agro-ecology of the Subak system from the consensus of water distribution, pattern, and the season for planting the paddy. This resolves the contradiction among the Subak. Subak temple, in lower position, has the same role from the water catchment area, Subak until Munduk/Tempek, where the catchment area is located in the same hilly or valley.

According to the Balinese, water comes from the water goddess, Dewi Danu, who protects lakes and other water sources. Hence, water needs to be channelized into the temple network, starting with the temple adjacent to a water source/spring water or Bedung), the temple adjacent to water irrigation, and until the temple is located in a paddy field. All of these temples create a temple network composed of a hierarchical position starting with Ulun Danu Castle (Castle for Princess Danu or Dewi Danu), located in the highest supreme position. On this island, there are several Pura Ulun Danu located in four lakes. The four are Batur Lake in Bangli District, Beratan Lake in Tabanan, Buyan Lake in Buleleng District, and Tamblingan in Buleleng District. In Batur lake, there is Pura Ulun Danu, which is located between Pura Ulun Danu Batur and Songan Village. The two Pura have a Pura network as their downline, which includes many Pura in the watershed area, hundreds of Pura at the Subak level, and thousands of Pura in the paddy fields of farmers.

The Hindu people called water "Tirtha," which shows its function not only to erase the dirty elements but also to purify the human soul. Water was used after the prayer, where Hinduism always performed prayer and used Tirtha as purified water to drink and sprinkle on their bodies as a symbol of cleanliness and to cleanse their physical and mental bodies. The ancient farmers of Bali recognised the importance of paddy fields as their main source of dependence on water as the main asset of natural resources for agriculture. This is included in the Balinese Hindu philosophy, where water is pure and sacred. This shows the local wisdom of the Balinese people in applying agricultural practices.

The relationship between the small castle, or Pura Subak network, and Tirtha, or holy water, in the context of ritual, symbol, and ecological wisdom further describes the complexity of the Balinese people and their social structure. The paddy planting season starts with Subak by performing the ceremony of Mendak Tirtha or Mendak Toya. The ritual or religious services in a ceremony that requires actions are meant to seek the blessing from the water goddess, or Dewi Danu, to maintain the quantity and quality of water so that paddy can grow and produce a yield and harvest as expected by the farmer. *Mendak Tirtha* begins at Pura Ulun Danu Batur with a delegation of farmers led by Jro Gde Mekalihan (two of the priests purified at Pura Ulun Danu) praying at the cliff crater of the Batur Mountain and bringing Tirtha into Pura Ulun Danu Batur. At Pura, the chain of ritual ceremonies involves Panca Pagenda, or five types of prayer arts according to the Hindu concept of loving God towards beauty. The five elements of panca pagenda consist of kidung or voice arts, kakawin or literary arts, gamelan or musical arts, igeligelan or dance arts, and painting, as well as carving art or visual arts.

Referring to the physical environment of a tropical climate with a combination of a line of several mountains in Bali Island, it is suitable for agriculture activity. Water from the catchment area in the mountains channels into rivers in the watersheds, such as the Pakerisan watershed, through an irrigation channel and to the land for paddy fields, either on flat land or in the hilly or ridge of the hilly area that maintains the topography of the soil. There are also intercrop plantations that maintain the small forest that co-exists with the rice terraces. The water irrigation distribution and management were maintained by the Subak organisation for a thousand years. Itsand produced the rice terraces' cultural landscape.

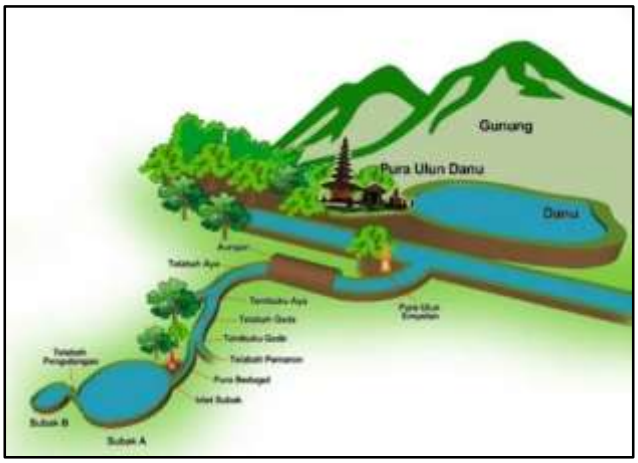

Figure 1. The Balinese ecological and cultural landscape with the Subak temple network.

Figure 1 describes the Subak temple network and its relations with the lake and river. The figure shows the hierarchy of Subak temple, starting with *Ulun Danu* Temple, the water goddess *Dewi Danu*, the temple which protects the lake and the natural resources and its physical environment, is located in *swah loka* or mountainous area or head parts. It is believed that it exists as part of the supernatural claims in Balinese Hinduism. Ulun Danu lake temple is dedicated to the water goddess.

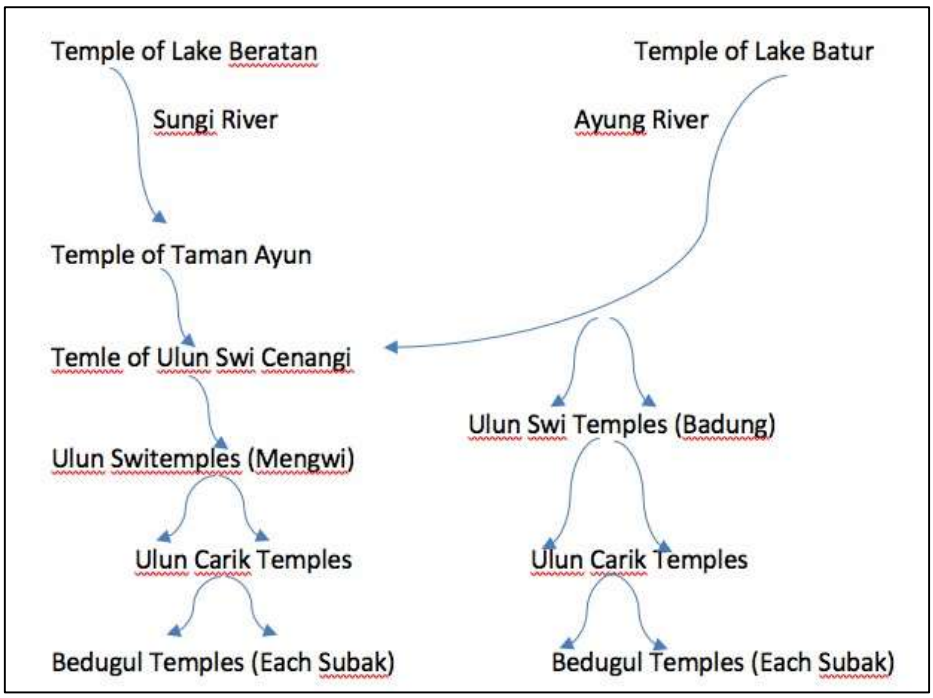

Figure 2. Balinese Water Temple Network (Lansing & de Vet 2012).

Religious symbolism and mythology are vehicles to convey traditional knowledge about the local environment, which develops a coherent system to manage natural resources. The spiritual dimension contains not only the practical knowledge but also the social structure that enables farmers to cooperate consistently and rationally through the hierarchical system of temples. Furthermore, the spiritual

dimension of Balinese water management ensures the resource's intrinsic value beyond its utilitarian purpose of growing rice.

The ancient Balinese implemented the *Tri Hita Karana* (THK) philosophy in managing their community assets and reflected on how they managed their physical environment. Their recognised three main parts, which are *bhur* or leg, *bhuah* or body, and *swah* or head, are manifest in their built environment and ecosystem. The *swah,* or head, is the mountain and hilly area located in the middle of Bali Island, the *bhuah,* or body, is the Subak, and the villages and the *bhur,* or leg, are the beach area. *Swah* needs to be managed as a catchment area, and the forest and lake need to be managed to irrigate the water regularly by using the Subak system. The biodiversity of flora and fauna in mountainous areas needs to be managed, while the hilly areas with cultural landscapes need to be maintained and sustained by mixed vegetation, staple crops, and hard-shaped trees mixed with shrubs. The Subak landscape and villages are located in *bhuah loka,* or bodies where villagers need to benefit economically and socially by sustaining the environment of agriculture activity. Volcanic soil from the mountain and water distribution from the upstream level of water followed by the contour of the soil topography provide a unique environment for the rice terraces. This knowledge represents the TEK of the Subak landscape for sustainable agricultural practices.

Subak is also responsible for managing their household either by making water available or managing water well and effectively for the paddy fields of the *Subak* members within the region. *Subak* conserves and maintains irrigation facilities as well as possible by ensuring irrigation in the region. *Subak* follows the existing rules called "Awig-awig." As a traditional institution having deep spiritual roots and having existed for hundreds of years, *Subak* performs its activities based on the philosophies of THK. There are awig-awig in written form, and some are in agreement with oral form. All forms of awig-awig are agreed upon in a meeting between members of the customary village community called *sangkepan*. The awig-awig that is ready to be implemented without any sanctions is called *pesuaran*, while the awig-awig that has been agreed upon and has sanctions is called *pararem*.

In the past, the Subak was considered a successful organisation at the farm level. This is based on several reasons; i. awareness of the common interests of its members in the form of the need for irrigation; ii. a genuine need from its members to be able to achieve something through joint activities; iii. a social bond that is always maintained in the atmosphere of a solemn religious ceremony; iv. a foundation that can be used as a guideline in the form of awigawig, which contains rules as basic guidelines that are deeply rooted in Balinese society; and v. the existence of assistance, services, and government policies for the development of Subak [46]. However, the Subak function is questionable in the current context of Balinese society.

4.2 Subak TEK as a sustainable agricultural practice

A well-coordinated water distribution system in Subak secures the downstream of the river. It avoids the water shortage upstream of the river, reflecting sustainable agricultural practises. Volcanic soil is rich in mineral nutrients such as potassium and phosphate, which is important for the farmer [47]. The nutrients fall through the river water canals and channels into the rice fields. The nutrients are absorbed by the rice for growth, and it demonstrates a perfect hydroponic system. Water consumption dominance in the Subak upstream has consequences in the Subak downstream due to a lack of food or nutrients [48]. Water irrigation from the Subak upstream to downstream resulted in a good pest control which can reduce plant disease cause by the pest spreading into a larger are of paddy field. This is also related to the paddy planting cycle and pest control. Failure to follow the rules is a subject to failure in the harvest.

The principle of the Subak traditional irrigation system is pest and water control, water shortage or pest damage. Upstream rivers share their water with the downstream river/Subak, and both parts will be

harvested simultaneously. So, the pest is under control. But, if the upstream Subak wants to save water as much as possible, the pest problems downstream will come upstream to attack and eat the rice. The upstream farmer worries about pests, while the downstream farmer worries about water. This interdependent relationship between Subak farmers downstream and upstream of the river creates a synergistic and harmonious relationship regarding pest control and respect for nature. Every farmer needs to plant on a fixed schedule to prevent the pest from migrating into other rice plots. Water control only works when every farmer plants the rice simultaneously based on a schedule agreed by the farmers so that the pest cannot migrate into other paddy plots.

The Subak system determines rice planting and irrigation times to maximise yield. The timing of planting is determined by the ritual calendar. The timing of the Nyunsung ceremony is the most critical moment in the farming calendar as it signifies the start of the planting season. Selecting the right time optimises the plant's need for rainfall and sunshine. The harvest occurs in the dry season, and pests minimise pest populations. This is an example of the management of resources, distribution, and the use of welfare-oriented irrigation water in a comprehensive manner, namely the welfare of the community in the watershed area [49] where the decision-making process considers the political, economic, social, and cultural aspects (religion). It represents the multifunctional ecosystem to achieve sustainable agricultural development

The Subak TEK meets the rules as an irrigation system in accordance with the "Irrigation Planning Standards." The network in the Subak system in Bali is almost the same as the existing technical network. This is based on the fact that the Subak field and its irrigation network which have four main functions, namely:

1. The main building is called *empelan* (weir) or open (intake)
2. Channel is called *telabah* (open channels) or *aungan* (closed channel)..
3. Overlays of plots that are part of a Subak called *Tempek* or *Munduk* are also equipped with buildings and channels to distribute water to all areas with a sewer called *Kekalen*
4. The collective disposal system, called *pengutangan*, is also owned by Subak, generally in the form of natural channels (*pangkung*).

Table 1. Subak traditional water irrigation system and irrigation planning standard.

Irrigation Planning Standard Network	Subak Traditional Water Irrigation System
The Subak weir	*Empelan*
Intake	*Bungas*
Primary Channel	*Telabah Gede*
Building for secondary	*Tembuku*
Secondary Channel	*Telabah*
Building for Tertiary	*Tembuku Pemaron*
Tertiary channel	*Telabah Pemaron*
Buildings for quarters	*Tembuku Cerik*
Quaternary Channels	*Tlabah Cerik*

The lake temple will hold a festival every 105 days, related to the number of days for rice planting in Bali. This cycle also determines the time to open and close the water channel to ensure that water is allocated efficiently and fairly. This effort shows the effect of local wisdom on the planting cycle [50]. Several Subak develop Subak Gede as one permanent unity among the Subak in managing the water irrigated from one watershed. Each subak has a dam and different sources of water, but they are all in the same watershed.

4.3 The spiritual aspect of Subak

Subak is not merely an irrigation system. The Subak system has very heavy and intensive ritual activities, distinguishing them from regular irrigation systems. Subak ritual ceremonies are part of the important implementation of THK, namely the Parhyangan aspect. For example, on Tumpek Wariga, a celebration day that comes once every 210 days, is a possession ritual conducted to express thanksgiving and gratitude to Ida Sang Hyang Widhi. Tumpek Wariga reminds people to nurture nature, which is connected to the Palemahan aspect of THK philosophy. Once every six months, Hindu people are reminded of how important it is to conserve nature (plants) through the ceremony of Tumpek Wariga. There are 16 types of ritual activities involved in Balinese rice planting, performed individually by farmers as members of Subak in their respective paddy fields, starting from taking water for irrigation to post-harvest activities (Table 2). The ceremony begins with "Mapag Toya/Mendak Toya," which is welcoming water or fetching from its sources, until the activity of keeping the harvest in the storage called Mantenin. After the Mapag toya ceremony, Krama Subak and Krama worked together to repair and clear the water irrigation channel to improve the water flow to the paddy field (Table 3). Every next step is followed by a ritual ceremony as a way to seek God's guidance. However, the Subak TEK and SES values are also depicted in Table 2. This result further helps to contribute to the body of knowledge of modern ecological knowledge.

Table 2. Types of ritual activities, implementation time, and purpose.

No.	Name of Rituals Involves TEK	Implementation Time	Purpose	Subak TEK & SES Values
1	Mapag Toya / Mendak Toya Ceremony	At the starting time to fetch water from its sources	Asking God for adequate irrigation water to fulfill the water need of the paddy fields	Knowledge to appreciate the existence of water irrigation.
2	Ngendagin / mamungkah / nuasen tedun Ceremony	Before performing agriculture activities at paddy fields	Asking permission from gods and goddesses living at paddy fields, as the manifestation of God, before farmers start planting as a part of agriculture activities at paddy fields	Redefine human interaction by seeking the blessing from God.
3	Pangwiwit / Ngurit Ceremony	Soon after the seeds are planted	Praying to God so that the planted seeds will grow well.	More time for seeds to develop.
4	Nuasen Nandur Ceremony	Just before planting seeds at the paddy fields	Praying to God so that the process of planting seeds can go well and smoothly	Give more time for seed development
5	Ngulapin Ceremony	Soon after planting rice at the rice fields	Praying to God so that the planted seeds can grow well and cause no damage	Develop abilities to adapt and survive in the new environment
6	Ngerestiti / Nangluk Merana Ceremony	After planting rice at paddy fields	Praying to God so that insects/pests do not attack the rice plants	Plant-pest control and management

7	Ngerorasin Ceremony	After the rice has been planted for 12 days	Praying to God so that the planted rice can grow well	Plant protection
8	Mubuhin Ceremony	After the rice has been planted for 15 days	Praying to God so that the planted rice can grow well	Plant protection
9	Mubuhin Ceremony	After the rice has been planted for 35 days (1 month).	Praying to God so that the planted rice can grow well	Plant-pest control and management
10	Nyungsung / ngiseh / ngelanus / dedinan Ceremony	After the rice has been planted for 42 days	Praying to God so that the planted rice can grow well	Plant protection
11	Biukukung / miseh Ceremony	After the rice has been planted for 70 days (2 months)	Praying to God so that the planted rice can grow well	Social capital through distributing offerings after rituals to farmers and people nearby
12	Nyiwa Sraya Ceremony	After the paddy flowers are thoroughly in the rice fields	Praying to God so that the paddy plants can keep growing well and can produce good harvest	Plant protection
13	Ngusaba / Ngusaba Nini / Mantenin Dewi Sri Ceremony	When the rice seeds start yellowing before being harvested	Praying to God so that the harvest will be a success	Water and soil conservation by drying rice-field
14	Mebanten Manyi Ceremony	At the harvest time	Praying to God so that the harvest can run smoothly	Adopt ecological principles during harvest
15	Ngerasakin Ceremony	After the paddy has been harvested	Expressing gratefulness and thanksgiving to God for the success of harvesting the rice and for getting ready for the coming planting time in the next season	Ecological restoration post-harvest time

16	Mantenin Ceremony	After the paddy is kept in the storage area	Expressing thankfulness to God since the rice has been kept well	Ecological restoration post-harvest time; food security

Modified from Coordinating Ministry of Human Development and Culture Republic of Indonesia, 2015.

Table 3. The implementation of Tri Hita Karana philosophy in Subak TEK.

Human with God (Parhyangan)	Human with Human (Pawongan)	Human with Nature - Subak TEK (Palemahan)
1. Mapag Toya Welcoming water, fetching from its sources.	Krama Subak	Water distribution
2. Ngendagin	*Nguun* is a farmer to farmer invitation to help the workers in the paddy field. Sekaa is a group of professional workers who work in paddy fields to get the fees. *Seeka memula* is for paddy plant, *Seeka numbeg* is soil tillage management, *sekaa manyi* is harvesting.	Soil Tillage
2. Numbeg	Nguun, sekaa	Tillage
3. Nandur	Nguun, Sekaa	Paddy planting
4. Mejukut or Ngorodin	Nguun	Clear the weeds
5. Manyi	Nguun, Sekaa	Harvest

Modified from Surata [51]

Rituals performed for Subak are classified as collective and individual rituals. A collective ritual is performed by subak members, groups of subak (*Subak Gde*), or across districts in Bali. This spiritual aspect differentiates the traditional irrigation system in Bali and other areas that have Hindu traditions. The collective rituals consist of *Mapag Toya or Mendag Tirta*, the rituals performed by a series of rituals at Buleleng, located at Ulun Danu Buyan Temple. ***First,*** *Ngaturang Pakelem or Mepelabuh****,*** is performed thrice a year at Ulun Danu Tamblingan Lake Temple to sustain the water; ***second***, *Ngubasa*, the rituals performed at Ulun Danu Batur Lake Temple on the full moon of *Kedasa* (around April or May); ***third,*** *Nangluk Mrana*, the rituals performed by the members of one Subak circle or joining several Subak groups on the beach to prevent pest attack; ***fourth***, *Neduh* Rituals performed by the Subak at Bedugul temple to retard the pest attack on the rice; ***fifth***, *Ngubasa Pari Wayah*, the rituals performed by the *Subak* at the peak time of rice; and ***sixth,*** *Ngubasa Nini*, the rituals performed to thank the goddess for their blessing and well-being and future safety. The majority of the rituals seek the goddess' blessing to sustain the water, control pests, and express gratitude for the harvest. Besides, there is an individual ritual performed by the farmer on his own in his rice plot. The rituals include *Nwasen/Mewinih* (begin at seed distribution/spread), *Ngendag Amacul* (soil processing), *Nwasen Nandu*r (planting), and *pekambuahan* – the rice age at 12 days, or moving from seedling plot to planting plot. *The Ritual Nwasen Nandur* is performed to seek a good *pertunasan* of the rice roots to grow in good condition.

The effort by the local government of Bali, expressed in District Regulation or Peraturan Daerah, helps in sustaining the Subak TEK. The protection of Subak as TEK is supported by the local regulations of Perda No.02/PD/DPRD/1972. It is stated that '*Subak is a Balinese custom that is characterised by socio-agricultural-religious or farming communities who adhere to their religion, which has historically been established since ancient times and developed as a land organisation in the distribution and management of water and other matters related to rice fields coming from water sources in certain areas'*. According to Perda No.23/1982, "*Subak is a customary law organisation that is socio-agrarian, religious, and historically grown and developed as an organisation in the water management field at the agrarian level." The* provincial regulation, however, is not enough to stop any development intervention that harms the Subak practices.

5. Discussion

Subak has been acknowledged as an outstanding universal value (OUV) of the agriculture system, which covers the TEK, is now facing a serious and threatening situation due to various factors which test its sustainability and resilience. This is due to the situational context of the current development that threatens the TEK sustain platform. This started with the Green Revolution in the 1970s, which affected the productivity of the rice paddy fields and the boom of the tourism industry in Bali. The Subak, like many other types of traditional irrigation systems, which are contextually based in nature, has potential application in the modern context of agricultural practices. Moreover, there are issues related to the poverty problems among the farmers of Subak. The water quantity decreases due to the deforestation activities to cater to the resort development in the mountainous hills and valleys of Bali. The Subak faces new challenges in the current development scenario due to natural degradation, which has the potential to weaken the harmonisation between humans and the environment. Subak culture is only effective as a ritual tradition to link the people with the Goddess, but in its implementation, Subak has started to degrade due to land conversion, professional transfer, poor economy, and young people who do not want to continue it.

The rapid development of the tourism industry is something that challenges the Balinese either directly or indirectly. It's had a tremendous impact on Balinese people in various sectors. For example, i. declining irrigated rice fields due to conversion, ii. declining of youth to become farmers, iii. fast cash from the tourism sector compared to agriculture activity, iv. river pollution and irrigated water in the water channels. The loss of water rights that affect the Subak's ceremonial and community-oriented ties is meaningless [52]. It is hoped that giving world heritage sites will empower the people to sustain their status in continuing the ancient culture of Subak.

This paper outlines the mechanism to sustain Subak TEK in the contemporary context of SES framework for Bali and its ESD entity; first, the integration of Subak into the formal curriculum for Teacher Education. It is to revive and sustain the Subak TEK as a pedagogical material for the students in local schools. To ensure this process will be sustainable, Subak, with its status as TEK, will need to be recognised as legitimate knowledge and taught as part of the school-based curriculum, including Subak as part of the teacher training [6]. The emphasis on three principles of eco-pedagogy covers ecological, cultural, and technological literacy and was used to develop the active-learning course by using Bali's Subak heritage as an example of place-based education [51]. The efforts are part of the teacher's module to improve the student's understanding of the subject matter (cultural heritage) and also the pedagogical skills through interactive learning. This includes the learning materials such as landscape stories, landscape mapping, photovoice, and film participatory video approach using the natural landscape of Subak as part of the learning tools. Thus, this process aligned with other aspects of Subak as TEK, such as cosmology, culture, and identity [7]. It is to strengthen the local student engagement in their local Subak system in the new context of learning.

Second, Subak-related courses in several local universities are part of the integration of ESD in the formal and local education systems in Universitas Mahasaraswati, Denpasar, Bali. 1) General ecology that introduces various concepts and issues in Subak (such as ecosystem, community, population,

habitat, biogeochemistry cycle); 2) Ecopedagogy that harnesses interlinks between science, environment, technology, and society through which we can learn about social-ecology from Subak; 3) Contextual biology teaching with Subak as a place-based learning; For postgraduate (master's degree), 1) Ecological Development Planning to enhance the capacity of the student to understand that the Subak system is a model of sustainable development since the system has sustained for more than a millennium; 2) Tourism Area Planning to design or develop a strategy to help Subak be an edu-tourism destination. This effort sustains the values and principles of Subak TEK in their modern education system. Third, preserving the social and cultural aspects of the Balinese philosophy of 'Tri Hita Karana' through the Tri Hita Karana (THK) Awards and Accreditation for tourism operators and hotels. It is an initiative based on local philosophy about harmony, which implements sustainability as a tool to prevent tourism development's impact on nature and culture in Bali. The award categories are (1) the initial screening to attract prospective participants. (2) Fundamental training for all participants in order to provide evidence to the assessor team.(3) completed the list of statements in the manual book. (4) Site inspection phases I and II for data tabulation and grade determination meetings.(5) The grade is announced.(6) The THK Awards and Accreditation will be presented in conjunction with the Balinese Food Festivals.The promotion of Subak TEK and their THK values helps to promote the ecological and natural values of Subak, which is part of the effort to strengthen the Balinese's SES framework by emphasizing the community-based tourism approach via their local wisdom. Hence, it is contribute to the future tourism planning and development.

Fourth, offer cultural CBT activity to sustain Subak with its cultural landscape. This is supported by the current practise where Pekaseh, who previously functioned as a water manager, has become the tourist guide. This can be found in the Subak water irrigation system in Jatiluwih rice terraces, which is part of the UNESCO cultural landscape and many other community tourism-based activities. Several CBT contributions to improve the economies of local communities are found in many countries across various communities and their resources. For instance, in rural communities [53], fishing villages [54], islands [55], urban heritage societies [56] and aboriginal communities [57]. Among the examples of the cultural CBT activity are: i. Visit the holy water, Tirtha at Tampak Siring; ii. Have a purification bath in a holy spring temple; and visit a local priest compound. Visit the holy spring water, the famous Tirta Empul holy spring, Gunung Kawi temples, and several other historical temples. Tracking the Pakerisan River and its watershed as one of Bali's UNESCO World Heritage Sites A spiritual journey to these important sites in this cultural walk. Several activities are also included to show and teach you the local culture. Subak, as one of the local heritage products, ideally has led to powerful community ownership, involvement, and benefits. Subak applies the concept of CBT, encouraging respect for local traditions, culture, wisdom, and natural heritage, which is tailored to the biosphere reserve program for conservation and community development [58]. As a result, Subak is viewed as a more sustainable tourism asset that reflects Bali's local culture, traditions, daily lifestyle, and behavior which helps to strengthen future tourism planning component.

Fifth, sustaining the Subak SES values is important to inherit the values for educational learning materials (Table 4). The values can be part of the modern environmental science content, which can be a lesson for today's development. The technological restoration technique was also proposed based on conservation functions that represent the SES framework's environmental system (Table 5). The involvement of adult learners in the proposed restoration ecology to sustain Subak helps to strengthen the ESD values and principles.

Tabel 4. Local wisdom values in Subak socio-ecological system, SES framework

No.	Aspect	Wisdow in Subak System	Sustaining the Subak SES Values
1	Software	• Develop the concept that water is created by God, so that it must be maintained in the best way possible • Develop a fair and proportional concept in the distribution of irrigation water, as well as the distribution of benefits and costs • Develop the concept of regulation in a clear and detailed manner in the implementation of Subak activities, which are outlined in the form of awig-awig (written rules) and unwritten rule	1.1. Water conservation with a proportional water distribution to the farmer community. 1.2. Awig-awig or written rules and perarem (unwritten rules) represent TEK Subak.
2	Hardware	• The topography of the Subak land is generally tilted and the rice fields are terraced, which aims to facilitate irrigation arrangements • Buildings are made with local materials that are easily available in the surrounding environment • Adopt the one inlet and outlet system in each block of farmer ownership, so that farmers can develop crop diversification systems to improve welfare. The system can also develop a water loan system to avoid conflicts. • There are clear boundaries between Subaks, and each Subak system has its own irrigation network • Allows the creation of traditional water tunnels that are traditionally made with principles that adapt to the environment.	2.1Subak TEK developed the rice terraces based on the topography which represent the traditional knowledge of Subak which is inherited through generations. 2.2 Utilise the local materials to build the traditional irrigation system, Subak. 2.3 Inlet and outlet system helps to avoid conflict among the farmer. 2.4 Systematic water distribution represents fairness in the social ecological system. It helps to maintain the irrigation network. 2.5 The creation of traditional water represents an ecological system to maintain the environment.
3	Organoware	• There is an autonomous, flexible, and clear hierarchical organizational system	3.1. Reflect social structure and efficiency for the

		• Clear management work period so that the replacement can be done in an orderly manner	water organization system.
4	Humanware	• There are always people who are willing to become administrators of the organization, even though the Subak organization is social • Devotion as a board is considered to be devoted to God, Subak members are very obedient to Subak rules because they are considered as a representation of God's rules	4.1. Reflect sustainability of the social system of the organization.
5	Infoware	• The Subak system as an organization is capable of being an information channel to achieve organizational goals, for example in the implementation of the Bimas, Inmas, and other Development Activities in the Agriculture Sector	5.1 Subak system has potential as open organization information link up with the current government such as *Bimas*, *Inmas* and etc.

Modified from Windia 2005.

Table 5. Subak TEK and the possible Restoration Socio-Cultural Ecology

No	Subak TEK Components	Conservation Function	Possible Restoration Ecology Significant Information
1	*Pangkedan* System	Soil - Management to prevent land erosion	Terracing system for water, soil and biodiversity conservation
2	Tillage system	Soil/crop - Regulations in lowland management with consideration of sustainability	Apply this system in the restoration project of Subak in the modern context.
3	Paddy fields	Soil conservation for carrying capacity	Include carrying capacity, biocultural diversity for sustainable living
4	Ban wood / vegetation	Germplasm - Play a role in the hydrological cycle	Maintain its function for the hydrological cycle
5	Barn	Food security by Subak and Community members	Conservation function by Subak and community members
6	Biotic components of paddy fields, rice, and maize	Rice field ecosystem	As a food source with an intercropping system

7	Subak artifact subsystem	Environmentally friendly	Artifacts used in subak activities are always related to the preservation of nature
8	Temples rituals and ceremonies	Spiritual motivation to respect life other than humans	Biocultural diversity conservation (interlinked between biodiversity and cultural diversity including language diversity)

Modified from Geria et al., 2019.

Sixth, in the broader context of learning, utilizing Subak as the learning material for online learning enhances the documentation of Subak TEK in the modern educational technology approach. The development of a module for the UNESCO MasterClass for Man and Biosphere Reserve Program and Natural World Heritage Site, Subak TEK, and the execution of the MasterClass involves researchers from Universitas Mahasaraswati and Universitas Denpasar [59].

6. Conclusion

Subak TEK is faced with various challenges due to its close nature related to its SES framework that has been changed. Subak as a sustainable agricultural practice may have difficulties due to demand for different land-use changes, such as hotels for tourism and urbanization. Hence, by using the spiritual and ritual practices of Subak which represent the SES practice by Balinese sustain the tradition as a way for them to stay connected to their God through the manifestation of Tri Hita Karana. Therefore, Subak as TEK in the Subak SES framework has potential to be utilize for future tourism planning in the current context of Bali.

The *Subak* as a live monument with strong humans institutions still has strong community capital values, which can be utilized for the potential of the Subak restoration projects in the context of Subak TEK framework by incorporating an integrated eco-agricultural organic method. Integrating the Subak organisations where the Pekaseh or head of farmers are part of the current government system is crucial to value their TEK and adjust the roles and function in the current context of development activities and future planning of the local area. Providing an interesting package for the agri-eco community-based tourism sector to attract youngsters is crucial, which can further improve the farmer's wellbeing by offering eco-knowledge-community-based tourism activities. To preserve the land, the gazettement of world heritage sites is crucial to control the land conversion for other purposes of development and preservation of natural and cultural heritage of Bali. Subak, as community-based tourism, has the potential for the enhancement program of Pekaseh as part of CBT for tourism planning.

The integration of the Subak TEK in the formal education system has been conducted to sustain knowledge over the generations through formal education. Hence, education for sustainable development (ESD) principles of action are suggested where more aggressive effort is needed in promoting Subak beyond the school or universities. Subak TEK has the potential to be applied in the restoration of the socio-ecological system, SES of Balinese people. Despite the minimum Subak and agricultural practices of the Balinese people, the ritual practice as the connection of the Balinese people to God has socio-cultural values of Subak TEK.

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