Subak, a Nature-based Solutions Evidence from Indonesia

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Abstract. Subak, an inherited communal water management in the agricultural system for centuries in Bali Island – Indonesia, has been widely known as a UNESCO World Heritage Culture since 2012. Subak’s philosophy “Tri Hita Karana” (three causes of prosperity) has become the foundation for Subak members to practice sustainable agriculture. Its institutional and operational practices were found to be a good example of ecosystem services management in a cultural way. In an attempt to assess Subak’s eligibility as a Nature-based Solutions (NbS) activities in ensuring the ecosystem services delivered to its people, we conducted a self-assessment using 8 criteria and 21 indicators based on NbS guidelines. The result shows that Subak addressed three out of seven societal challenges as a core of NbS: environmental degradation and biodiversity loss, food security, and water security. We also identified some problems and challenges faced by Balinese and Subak in terms of the system’s sustainability. We concluded that Subak could be categorized as an NbS, specifically NbS Type 2 for sustainability and multifunctionality of managed ecosystems. Supports from the central government both in terms of regulatory and policies are needed, as well as promoting Subak to other related sectors such ecotourism.

1. Introduction

1.1. Nature-based Solutions (NbS)

For decades, nature conservation has been treated as a marginalized element in national and global agendas. Nature conservation is included in the agenda only if it is considered profitable, but on the other hand, it is considered a development barrier. The conflict of interest between nature conservation and development or economic growth is getting worse leading to the neglect of nature conservation. It caused the depletion of natural resources that leading to the loss of biodiversity, and the emergence of complex socio-cultural problems. However, after the Sustainable Development Goals from the United Nations were coined, scientific-based consensus on how essential nature is for the survival and sustainability of the quality of human life began to grow and become a global concern. Then the idea of Nature-based Solutions appeared, initiated by the International Union for Conservation of Nature (IUCN) with a general goal is to help in protecting, managing, and restoring the environment which will ultimately lead to tangible-intangible and sustainable benefits for human wellbeing.
Nature-based Solutions (NbS) are defined by the International Union for Conservation of Nature (IUCN) as “actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” [1]. More generally, the term “nature-based solutions” can be used to describe alternative and non-traditional approaches to environmental issues, like a forest fire, drought, or flooding, by utilizing natural capital. The term NbS was firstly coined by IUCN in 2009 and is considered as an umbrella framework for an ecosystem-based approach. The framework is also addressing Natural Solutions (the role of protected areas in combating climate change), Ecosystem-based Adaptation (EbA), Ecosystem-based Disaster Risk Reduction (Eco-DRR), Green Infrastructure (for economic growth and investments, in the urban context), Natural Infrastructure (for a sustainable Integrated Water Resource Management), and Holistic or Regenerative Landscape management [2].

In the last decade, NbS issue has become widely recognized and practiced worldwide, as a climate manifesto to name some [3]. Although the NbS assessment guideline was just launched in 2020, many countries reported their NbS contributions under different or simple approaches. Especially in developing countries, NbS has not been well known and adopted due to economic growth prioritization that marginalized environmental issues and sustainability for human well-being. Thus, local knowledge and wisdom which mostly consider nature-based solutions principles are important to bring them up. In Indonesia, local NbS assessments following IUCN guidelines have never been done before. Thus, based on these arguments, the world’s famous Balinese Subak was chosen as a study case for potential NbS evidence from Indonesia.

1.2. **Subak**

Subak is defined as a traditional organization for water use and or plant use management under the certain farming unit in indigenous peoples in Bali Island, Indonesia, which is characterized by socio-agricultural, religious, and economy that has historically continued to grow and develop [4]. Subak was first coined after implicitly written on some historical inscriptions: Sukawana Inscription in 882 AD stated wetland and dryland agriculture, and Pandak Badung Inscription in 1071 stated Kasuwakan or Kasubakan and Subak afterward [5]. One publication also stated that Subak was known probably 393 years since the beginning of the development of the agricultural system in Bali [6]. Therefore, Subak attracts special interest worldwide because of its uniqueness and distinctiveness of Balinese wisdom in environmental-based agricultural practices within their natural and cultural landscapes.

The ritual components of Balinese culture and Hinduism that have survived for almost a millennium, the unique landscape that reflects the harmonious interaction of humans and nature on the volcanic island, as well as governance that has democratic and egalitarian characteristics, are outstanding universal values (OUV) that are not found elsewhere in the world. Therefore, in 2012, the UNESCO World Heritage Committee designated Subak as a World Cultural Heritage, under the theme “Cultural Landscape of Bali Province: the Subak System as a Manifestation of the Tri Hita Karana Philosophy” covering an area of 19,500 ha and 1,454.8 ha of buffer zones [7].

Tri Hita Karana (three causes of prosperity) philosophy consists of *parhyangan*, *palemahan*, and *pawongan* principles. The principle of *parhyangan* is reflected in a series of rituals carried out both at the farmer level and the Subak level, from starting agricultural activities until storing the harvested rice in granaries. The principle of *palemahan* is implemented by making paddy fields without destroying the contours of the land, building and maintaining irrigation canals. The principle of *pawongan* is demonstrated by the existence of a Subak organizational structure and the preparation of *awig-awig* (Subak regulations) to maintain harmonious relationships among Subak members. This ancient irrigated agricultural system serves small-scale landholders mainly in lowland paddy fields landscape [8] within a shared common watershed.

1.3. **Objectives**

Despite its uniqueness and eco-agricultural practices, Subak has been undergoing some serious problems that threaten its sustainability, both internally and externally [9–11], whereas it provides promising
activities and concepts to be recognized as natural-based solutions for agriculture. In an attempt to assess Subak eligibility as a Nature-based Solutions in Indonesia, we conducted a preliminary self-assessment based on relevant reports and publications. The result would provide some evidence which are beneficial for policy makers’ support and maintains Subak as the national treasure both in the cultural landscape and indigenous wisdom for an eco-friendly agricultural system that is worth for people’s sustainable wellbeing.

2. Materials and Method
We conducted descriptive research by using secondary published data from various online resources, descriptive analysis, and NbS assessment.

2.1 Case study area
Bali is one of Indonesia’s archipelago provinces, consisting of 33 islands that covering approximately 5,780.06 km² in size not including its sea territory. It has high potential resources on tourism, coastal and marine, as well as crop plants to support its community’s wellbeing. Its geographical position is spanning between 08º03’40” - 08º50’48” South Latitude and 114º25’53” - 115º42’40” East Longitude, embracing 9 regencies/municipalities and 636 villages [12].

2.2 Data collection and analysis
Subak data were collected from literature search under topics various keywords, e.g. ‘Subak’, ‘agriculture Bali’, ‘irrigation Bali’, ‘world heritage culture + Subak’ from online sources to gather information concerning Subak’ history, definition, regulation, and current implementation. By reviewing information from these literatures, challenges and problems faced by Subak in terms of NbS can be identified.

2.3 NbS Assessment
Assessment for Subak as NbS potential was carried out following particular standard by IUCN using 8 criteria and 28 indicators [2,13]. Subak activities were recorded, classified, and check-listing to the given NbS criteria and indicators based on obtained evidence. For this study, we slightly modified the scoring step into check-listing, thus the adherence level of intervention to the IUCN Global Standard for NbS was not calculated to produce a traffic light assessment result.

3. Results and Discussion
3.1 Main activities and their impact
Subak’s main activity was the regulation of irrigation and cropping patterns based on the Tri Hita Karana philosophy, which followed by the principles of soil and water conservation [14], provides optimal results and social justice [15]. In other words, the practice of Subak is a form of sustainable agricultural practice.

Prior to the advent of modern agriculture within the green revolution framework, Subak practices were able to manage water for terraced rice fields communally. Subak system provided fair harvests which relatively safe from pest attacks and conducted participatory problem-solving in community leaders’ regular meetings. After replacing the Subak system with the green revolution approach, some chaotic conditions happened not only in water management and crop yielding [15] but also in social-economic changes [16]. There were frequent pest attacks, water pollution, and extraordinary crop failures, which had never been experienced before. Therefore, the Subak community is getting back up little by little, starting from a few people until finally covering wider community within the same watershed to restore the concepts of their original wisdom in water management for their agricultural system. These adaptive actions have created multi-scale cooperation that leads to self-organized critically (SOC), which is considered as adaptive cooperative management [15]. It demonstrated Subak’s community spirit in nature-based problem solving towards environmental changes. They prefer
applying their inherited local wisdom and not against nature but somehow adaptive to cope with the needs and changes as long as they live in harmony with nature.

Subak system can carry out irrigation management based on harmony and togetherness under the principles of the Tri Hita Karana (THK) concept, and on that basis, the system can anticipate the possibility of water shortages (especially during the dry season), by managing the implementation of cropping patterns according to successful possibilities. Furthermore, the Subak system as a compatible technology basically has the opportunity to be transformed, as long as its compatibility values are met [10].

3.2 NbS Assessment

We identified that a nature-based solutions approach has been applied in Subak agricultural system for centuries, but in some periods were neglected when the modern agricultural approach as part of the green revolution took into force in a top-down manner. The entry of the green revolution into the Subak system caused the Kerta Masa had no longer been considered important as a guidance for regulating water and communal rice fields. The rice seeds grown are not from local varieties, and pesticides and inorganic fertilizers are widely used. Most Subak farmers could start their own cycle of rice fields depending on their individual readiness, not taking into account the season and water availability. Over time, this 'new' practice began to cause problems, such as pest infestation and water scarcity that led to crop failure and food insecurity, which is similar to the previous study [17].

Stakeholder engagement in assessing NbS is needed [18]. In this study, we conducted a self-assessment following the given guidelines by IUCN [2] but in a simplified way, based on reports and publications. We succeeded to qualitatively assessing all criteria and indicators that are met by Subak as NbS potential without further details on intensity values which need in-depth review and direct observations. The result of our self-assessment is presented in Table 1, can be used as a baseline for a more in-depth NbS assessment. Overall, it is observed that Subak addresses three of seven societal challenges, which are food security, environmental degradation, and biodiversity loss, as well as water security.

NbS is divided into three types: 1) Type 1 – Better use of protected/natural ecosystems, 2) Type 2 – NBS for sustainability and multi-functionality of managed ecosystems, 3) Type 3 – Design and management of new ecosystems [19]. Using this classification, Subak with its main activity in the form of sustainable agriculture practices can be classified as NbS Type 2 for the sustainability and multi-functionality of the ecosystem that has been managed. In the context of food security, “Subak has an important role for water allocation and distribution, resource mobilization for operations and maintenance, fundraising, conflict management, and ritual performance” [20].

Table 1 Self-assessment result of fulfilling the NbS criteria for Subak case study

| Criteria and Indicators | Case conditions & evidences |
|-------------------------|-----------------------------|
| 1. Societal challenges  |                             |
| C-1.1 The most pressing societal challenge(s) for rights-holders and beneficiaries are prioritized | ✔ | Subak is an important means to achieve food security [21–23], water security [14], and are progressively transforming to overcome environmental degradation and biodiversity loss [24]. |
| C-1.2 The societal challenge(s) addressed are clearly understood and documented | ✔ | Subak administration records regulations and agreements on water distribution, pest control, harvesting, and production [24]. |
| C-1.3 Human well-being outcomes arising from the NbS are identified, benchmarked, and periodically assessed | ✔ | Rice harvests among Subak members are equalized [15] and documented periodically and used to determine the contribution and penalty of each member [24]. |
| 2. Design of NbS is informed by scale |                         |
C-2.1 The design of the NbS recognizes and responds to the interactions between the economy, society and ecosystems ✔ Subak’s philosophical foundation and original work scheme promotes social interactions among its members, including women empowerment, while using nature-friendly approach in cultivation and pest control, and managed to improve farmers income compared to pre-Subak [21,23,24]

C-2.2 The design of the NbS is integrated with other complementary interventions and seeks synergies across sectors ✔ Bali Regional Regulation No. 9 of 2012 regulates the organizational structure as well as fostering and working relationships between Subak and local governments that can formulate solutions to problems related to other sectors such as conflicts over water resource allocation [25]

C-2.3 The design of the NbS incorporates risk identification and risk management beyond the intervention site ✔ Subak considers the risk of pest damage in synchronizing irrigation schedules between upstream and downstream [15].

3. NbS results in a net gain to biodiversity and ecosystem integrity

C-3.1 The NbS actions directly respond to the evidence-based assessment of the current state of the ecosystem and prevailing drivers of degradation and loss ✔ responding to loss of soil fertility, eutrophication in the river, and biodiversity loss due to previous green revolution, Subak are now gradually returning to its previous practice of organic farming [24,26]

C-3.2 Clear and measurable biodiversity conservation outcomes are identified, benchmarked, and periodically assessed ✔ driving factors causing degradation and loss were identified [27]

C-3.3 Monitoring includes periodic assessments of unintended adverse consequences on nature arising from the NbS ✔ The use of local rice is encouraged due to its higher survival rate and price compared to non-local varieties [24,26,27]

C-3.4 Opportunities to enhance ecosystem integrity and connectivity are identified and incorporated into the NbS strategy ✔ Each planting stage involves a traditional ceremony which indirectly becomes a form of monitoring problems that are documented by the Subak administrator [24,28]

4. NbS are economically viable

C-4.1 The direct and indirect benefits and costs associated with the NbS, who pays and who benefits, are identified and documented ✔ Awig-awig regulates members’ contributions and penalty according to work activities, amount of harvest, land area owned; payment for water temples operational in exchange to the right to water springs, while the administrator documents these transactions [24,25].

✔ Awig-awig in Subak structure regulates the mechanism for calculating and paying contributions according to the area of rice fields [6,8,21,24]

✔ Ecosystem services were assessed using FFI’s Guidance for the Rapid Assessment of Ecosystem Services (GRACE), involving biodiversity, cultural, and recreational values [27]
C-4.2 A cost-effectiveness study is provided to support the choice of NbS including the likely impact of any relevant regulations and subsidies.

C-4.3 The effectiveness of the NbS design is justified against available alternative solutions, taking into account any associated externalities.

C-4.4 The NbS design considers a portfolio of resourcing options such as market-based, public sector, voluntary commitments, and actions to support regulatory compliance.

5. NbS are based on an inclusive, transparent, and empowering governance process

C-5.1 A defined and fully agreed upon feedback and grievance resolution mechanism is available to all stakeholders before an NbS intervention is initiated.

C-5.2 Participation is based on mutual respect and equality, regardless of gender, age, or social status, and upholds the right of Indigenous Peoples to Free Prior and Informed Consent (FPIC).

C-5.3 Stakeholders who are directly and indirectly affected by the NbS have been identified and involved in all processes of the NbS intervention.

C-5.4 Decision-making processes document and respond to the rights and interests of all participating and affected stakeholders.

C-5.5 Where the scale of the NbS extends beyond jurisdictional boundaries, mechanisms are established to enable joint decision making of the stakeholders in the affected jurisdictions.

6. NbS equitably balance trade-offs between the achievement of their primary goal(s) and the continued provision of multiple benefits

| 5. NbS are based on an inclusive, transparent, and empowering governance process | ✔ Subak reduce irrigation cost [21] and increase farmers income higher than that of non-Subak farmers [30].
| | ✔ Subak’s synchronized planting schedules and work scheme was proven to be more effective, environmentally, and socially beneficial compared to the green revolution farming method [15,24].
| | ✔ Definition and operational management of Subak is stated in provincial regulation [4], more practical recommendation in [27].
| | ✔ Subak has universal noble values that are very relevant to the concept of sustainable development. These values are the manifestation of Tri Hita Karana philosophy [4].
| | ✔ Recommended [17] and studied by [27].
| | ✔ Subak is an organization of wetland farmers who get irrigation water from a common source, owns one or more Bedugul Temples, and have the freedom to manage their household as well as in dealing with outside parties. This definition contains both physical and social aspects. The physical aspect of Subak is the expanse of rice fields with all of its irrigation facilities, while the social aspect of Subak is an autonomous irrigation farmer organization [31].

| 6. NbS equitably balance trade-offs between the achievement of their primary goal(s) and the continued provision of multiple benefits | ✔ Every Subak must have written regulation (awig-awig) from a mutual agreement among its members [24], while interactions among adjacent subaks are based on Tri Hita Karana and Bali Provincial Regulation on Subak [4].
| | ✔ Subak’s philosophical foundation, Tri Hita Karana, asserts the obligation to mutual respect and strong relationship among members [17,32,33].
| | ✔ Written in UNESCO World Heritage Culture’s document for Subak Cultural Landscape [7].
| | ✔ Subak documents all activities in more than a dozen books including meeting minutes and cooperation among its members [24], recognized well in Bali Provincial Regulation No. 9/2012 [4].
| | ✔ Written in Bali Provincial Regulation No. 9/2012 [4].
C-6.1 The potential costs and benefits of associated trade-offs of the NbS intervention are explicitly acknowledged and inform safeguards and any appropriate corrective actions

✔ Written in Bali Provincial Regulation No. 9/2012 [4], and ruled by awig-awig (Subak’s written regulation based on collective decisions).

C-6.2 The rights, usage of, and access to land and resources, along with the responsibilities of different stakeholders, are acknowledged and respected

✔ Subak allows the borrowing of water between Subak members, regulates the rights and responsibilities of landowners and cultivators, recognizes the obligation to pay to water temples for the right to access to springs [17,24]

✔ Subak has written regulation called awig-awig which also includes mutual agreements between members and stakeholders

C-6.3 The established safeguards are periodically reviewed to ensure that mutually agreed trade-off limits are respected and do not destabilize the entire NbS

Has not been identified.

7. NbS have managed adaptively, based on evidence

C-7.1 An NbS strategy is established and used as a basis for regular monitoring and evaluation of the intervention

✔ Executed according to the capacity of the Subak community in Subak institutions based on the Tri Hita Karana philosophy
✔ Written in Bali Provincial Regulation No. 9/2012 [4]

C-7.2 A monitoring and evaluation plan is developed and implemented throughout the intervention lifecycle

C-7.3 A framework for iterative learning that enables adaptive management is applied throughout the intervention lifecycle

8. NbS are sustainable and mainstreamed within an appropriate jurisdictional context

C-8.1 The NbS design, implementation, and lessons learnt are shared to trigger transformative change

✔ A transformative change of Subak from Bali to Flores has been studied, stating Floresian capability of adopting the system, as long as the process was in line with the local culture and norms [34]. Adopting Subak outside Bali Island also proven to be beneficial for farmers in Southeast Sulawesi [30].

✔ the Subak system as a compatible technology basically has the opportunity to be transformed, as long as its technological equivalence values are met [10].

C-8.2 The NbS informs and enhances facilitating policy and regulation frameworks to support its uptake and mainstreaming

Responsibility handover from local government to Subak due to financial reasons was revealed [9].

C-8.3 Where relevant, the NbS contributes to national and global targets for human well-being, climate change, biodiversity, and human rights, including the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP)

✔ Subak’s productivity was significantly higher than that of non Subak [17], rice self-sufficiency, and sustainable agriculture [32]. Subak potentially contributes to the nation’s ecotourism development [28], play important roles in water allocation and distribution, resource mobilization and maintenance.
fundraising, conflict management, and ritual performance [20].

✔ Subak is responsible for building capacity to enhance their productivity, income, and peasant’s well-being [4]

✔ Subak has been recognized as the UNESCO World Heritage Culture since 2012 that worth protecting and sustain [7].

Notes:
✔ = mild to strong evidence;
× = no or weak evidence

3.3 Potential benefits and opportunities of Subak as NbS
The 2019 Climate Action Summit in Brussels brought great political attention to the power of NbS for sustainable development and climate action that was followed by the NbS Manifesto for climate change. According to the IPBES Global Report, there are enormous contributions that nature makes to people worldwide in a very wide range of people’s livelihoods [35]. This report also emphasized many aspects of nature-based solutions that can be taken into land-based climate change mitigation, SDGs implementation cost-effectively, cities and people resilience towards global changes, sustainable management and conservation of carbon-storing, sustainable technology through social innovation and investment, sustainable urban planning, integrated approach for sustainable freshwater and cities, disaster risk control, to name some. NbS was also found beneficial to the health of children and elderly in urbanization areas [36]. In other words, NbS is a promising environmentally-friendly approach to ensure the ecosystem services are delivered for human well-being.

Related to NbS values above, Subak cultural landscape and systems were proven to be beneficial in food productivity and security, reducing risk on water scarcity especially for irrigation-related paddy fields, reducing disaster risk in terms of terrain landscape that avoid landslides, as well as safeguarding environmental degradation and biodiversity loss (for relevant references see Table 1). By maintaining nature-based solutions concepts in Subak will potentially encourage co-production of initiatives to ensure ownership and stewardship that address critical needs while conserving nature, restoring biodiversity, maintaining and enhancing ecosystem services. This eventually invites external supports to make Subak more sustainable in ecosystem function, economic stability, and social equity.

3.4 Identified challenges and problems
At the national level regulation, Subak is only implicitly mentioned in the context of “water user farmer associations” in Presidential Regulation No. 20 / 2006 concerning Irrigation. In terms of cultural value, Subak in general definition was considered protected by Law No. 5/2017 concerning Cultural Advancement, while its territorial aspect is ruled by Government Regulation No. 13/2017 concerning the National Spatial Planning, but neither of them explicitly mentioned Subak. Previously, Subak is explicitly mentioned in the national regulation concerning irrigation.

At the regional level, Subak is protected in a formal legal through the Bali Provincial Regulation [4]. This regulation has become more important when the national regulation governing irrigation did not mention Subak explicitly in its irrigational regulation anymore, unlike previous regulation. This provincial regulation takes responsibility for building, maintaining, and repairing primary and secondary irrigation networks from Subak to local governments, thus indeed very beneficial for Subak in terms of budget efficiency. It was reported that water demand has been increasing since the 1970s not only for agricultural purposes but for non-agricultural needs as well [37].

Furthermore, some publications concerning Subak status as environmental-based solutions stated challenges or threats to its sustainability. Some issues were lacking government supports [38], continuing stress from other sectoral development [10,17], declining farmers regenerations [10], trading-related strategy, land-use changes from irrigated agriculture to non-agriculture land, water
scarcity, environmental quality depletion, irrigation network management handover from local government to Subak, and financial constraints [9]. Furthermore, modernization and technological impacts, discontinuity of certain social activities, were also considered as a hindrance for Subak sustainability [39]. Many recommendations have been published to overcome these problems but many of them underlined the raising awareness of Subak significant role to people and environment, as well as government interventions and supports to help its sustainability. Key elements of Subak are farmers, paddy fields, water, pura, and authority both internally (Subak as a local institution) and externally (local governments), therefore those elements are priority of concern in order to make Subak as NbS sustainable.

Effectiveness, as well as economic and resource efficiency are the key factors of NbS in solving environmental problems [40]. In Subak case, Tri Hita Karana (THK) philosophy plays important role in Subak and Balinese people, mainly in their socio-culture aspect but not strongly concern with the economic one. This is in line with SWOT analysis on Subak’s role for the economy that showed a weak delivery or activities related to the inadequacy of human resources in managing their economic activities, weak power compared to external competitors especially from private companies, as well as existing conflict of interest in rural economic development [41]. Sustainability of economic and socio-cultural activities in Subak was suggested to be an aggressive strategy by taking full advantage of its strengths and opportunities [41]. Thus, governments need to support such powerful strategies or policies to improve the economic aspect and human resources capacity building for Subak. In terms of resource efficiency, THK philosophy provides direction on how subaks and their members manage and utilize limited natural resources consisting of land or agricultural land, irrigation water, plants, and animals to provide welfare for all Subak members [42]. In related to human resources, there was low regeneration of farmers in terms of numbers of farmers and numbers of household practicing rice cultivation [9,10] due to a paradigm shift between agriculture and tourism priority in Balinese people as well as in governmental priority program.

We argue that Subak current conditions were strongly affected by the change of local development policy directions. Current policies concerning development and economic growth in Bali tend to be more committed to the tourism development sector. The tourism sector has become a top priority as the main source of Bali's economic growth, leading to weak support for agricultural sector including Subak. Furthermore, the provincial regulation concerning Subak was not clear on the rule and responsibility of local government in terms of water management. Lately, there was also a sort of responsibility handover of irrigated-agriculture systems from the local government to Subak that made Subak operational system even worse.

Subaks consist of hundreds of Subak with their nature and characteristics. Even in their daily activities in governing Subak and managing irrigation systems, there are a variety of local wisdom, knowledge, and mutual agreements under the same THK philosophy among subaks. Thus, their achievement, crop yields allocation, and how they implement adaptive management toward environmental changes are also different. We carried out this research for a general Subak system and not differentiating every site, so we suggested identifying and assessing the NbS potential for a specific Subak to narrow the scope but with more in-depth analysis to improve the sustainable solutions.

3.5 Recommendation for Interventions to Improve Subak as NbS

All arguments above lead us to summarize and recommend a few interventions to improve Subak as NbS. Those are as follows:

1) Proactive and more aggressive efforts to mainstream Subak, especially for governments. Monitoring and evaluation have to be done periodically;

2) Elaborate quantitative studies and preferably multi-, inter-, and transdisciplinary approaches. These include natural resource and ecosystem services valuation, both tangible and intangible factors, which eventually enables payment for ecosystem services (PES) scheme to support Subak’s financial needs;
3) People-centered approach to improve the solutions, basically on rights (particularly secure land tenure for indigenous peoples and local communities), reorientation toward agroecological food production, also on conservation and restoration of forests, with no further loss of primary ecosystems which ensure water supplies;

4) Collaborative governance in prompting a shift from large-scale centralised infrastructure to localized nature-based solutions;

5) Consider ecological fiscal transfer (EFT) scheme through “Transfer Anggaran Kabupaten berbasis Ekologi” or TAKE to overcome financial constraints in Subak management. This scheme enables local government to better allocate budget for their planned expenses in certain fiscal year built upon ecosystem-based local development;

6) Awareness of NbS concepts at all levels.

4. Conclusion

Based on the preliminary self-assessment above, Subak actually has met all criteria as Nature-based Solutions, although its intensity or depth has not to be measured quantitatively in this study. Subak can also be categorized as NbS Type-2, which is implemented for sustainablity and the multi-functionality of managed ecosystems. A more in-depth assessment under the IUCN guidelines is needed, elaborating more relevant evidence and stakeholder judgment. We underlined the importance of direct research and innovation budgets toward Subak as NbS, which mimic nature, not against nature. TAKE fiscal scheme under the EFT is worth trying as one alternative solution to address this financial matter.

Collaboration between stakeholders (including private sectors/community social responsibility), strengthening the role of organizations, and the active involvement of cultural communities in policymaking regarding irrigated-agricultural systems have to be a priority. Thus, it is very possible for the birth of co-creation from the actors involved to overcome problems and balance trade-offs or disturbances that can occur at any time. With co-management and co-creation, adaptive management will be obtained that is flexible in responding to and solving problems faced collectively. Accordingly, Subak needs to be well mainstreamed into strategic programs, policies, and regulations; Subak has to be included in regional infrastructure, procurement process, and development planning. This is in line with our assessment result above. Furthermore, stakeholder engagement in the assessment and evaluation process is encouraged to achieve the NbS effectiveness.

The NBS concept relies on five key points, namely recovery, social issues, infrastructure, management, and protection, and is aimed to addressing social challenges and environmental problems effectively and adaptively. This is almost the same as the Subak system which considers Subak as a concept of life for the Balinese people themselves. NbS is a program with multiple and multiscale benefits [19]. There were lots of challenges for Subak to thrive as a promising NbS to ensure its ecosystem services were delivered for people's wellbeing. Therefore, Subak really needs to be supported by the central and local government both in terms of regulatory and political support, as well as in promoting Subak to become a magnet for other sectors and integrating them.

Published studies on Subak irrigation systems are mainly focused on the qualitative and monodisciplinary approaches in social sciences with some extent on economic, but fewer attention on natural sciences, including ecology, hydrology, and natural resource management. We recommend more studies on quantitative and dynamics approaches that use inter-, multi-, and even trans-disciplinary approaches elaborating ecology, economics, and socio-culture as the three pillars of sustainability. By doing far beyond monodisciplinary approaches that combined with stakeholder engagement would hopefully promote stimulation for the protection and management of existing Subak, as well as similar rice terrace system beyond local and regional scales.

Spirits of maintaining the subaks' universal values and local wisdom have to be sustainably managed and supported that potentially be adopted or transformed to other sites even outside Bali. Based on empirical data, modernization of the agricultural system (green evolution) was not always suitable to apply anywhere.
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