Contributions of ecological programs to sustainable development goals in Linzhi, over the Tibetan Plateau: a mental map perspective

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Abstract: Ecological programs (EPs) can reverse the degradation of ecosystems and promote the achievement of the sustainable development goals (SDGs). The public understanding of the role of EPs in the context of SDGs can influence people's participation and decision-making. However, there is a lack of insights into the systematic patterns of cognitive associations between the programs and SDGs. Here we identify the public perception of EPs using mental maps that illustrate how people relate nine EPs to SDGs linked to nature, human well-being, and economic productivity. Based on information collected from stakeholders, it was found that "Soil and Water Loss Control", "Sand Prevention and Control", "Shelterbelt Construction", and

"Wetland Conservation" were indicated as the key programs for the achievement of SDGs in Linzhi. The mental map of the majority of the people identified trade-offs between the environmental/social and economic sustainability elements supported by EPs. Some people related multiple EPs to social and economic sustainability elements, while others primarily saw multiple EPs as targeting the environmental and economic sustainability elements. The dominant mental map here identified could serve as a model for engaging in, and communicating, ecological programs. We suggest a direction for addressing SDG trade-offs through ecological program-based management, which is based on three aspects: priority adjustment, integrated portfolio, and stakeholder engagement.

Keywords: ecological programs, sustainable development goals, questionnaire survey, mental map, Tibetan Plateau.

1. Introduction

Ecological programs (EPs) can restore and rebuild the structure and function of ecosystems to produce a range of valuable ecosystem services that benefit both human and nature (Costanza, 2012; Blicharska et al., 2019; Fu, 2020). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) concludes that protecting and restoring degraded lands makes sense from the ecological, economic and social points of view, and it is essential to meet the sustainable development goals (SDGs) established by the United Nations (UN) (UN, 2015; IPBES, 2018).

Recognizing the key role of restoration, in 2019 the UN declared the "Decade on Ecosystem Restoration" to accelerate the recovery process, and put the world on track for a sustainable future (UN, 2019a). The UN Decade is from 2021 to 2030, which is also the deadline for the SDGs. Therefore, focusing on the contribution of ecological protection and restoration to these sustainability goals has both an important scientific and practical significance.

Sustainable development goals provide a broad framework for government departments, ecological protection personnel, local residents, and other stakeholders to engage in, and communicate, ecological restoration to promote sustainability (UN, 2019b). Increasing stakeholder participation and support, so that these actors can undertake their own activities, is important to contribute to the overall vision of the UN SDGs and UN Decade (Aronson et al., 2020). Understanding the views of stakeholders on the role of EPs can inform sustainable development communication, providing the information that is more likely to be supported and shared, thereby allowing practitioners to promote land-system sustainability policies in a way that is consistent with people's views.

Using the responses of stakeholders, extensive efforts have been devoted to how policy makers should understand and use the information related to EPs in the context of sustainable development, to coordinate and shape government policies. A number of studies have comprehensively evaluated the contributions of single ecological program to multiple SDGs, or those of multiple programs to individual goals (Bandyopadhyay

66 and Tembo, 2010; Petursdottir et al., 2013; Sheng et al., 2019; Li et al., 2021). In
67 particular, the “Grain for Green Program”, “Natural Grassland Protection Program”,
68 “Natural Forest Conservation Program”, and “Wildlife Conservation Program” have
69 attracted considerable attention (Viña et al., 2016; Mavah et al., 2018; Wu et al., 2019).
70 Furthermore, studies have focused more on the impacts of ecological restoration on
71 vegetation growth and biodiversity, resident income, food, and livelihoods (Zhang et
72 al., 2021a; Cao et al., 2021). Yet, little is known about the contributions of multiple EPs
73 toward multiple SDGs. A systematic assessment of their role is essential for portfolio-
74 wide planning, because each program will probably contribute to achieving several
75 SDGs, and each SDG will be addressed by several programs (Bryan et al., 2018). While
76 some information is available about the synergies and co-benefits of land management
77 programs for SDGs on average (Bryan et al., 2018; Smith et al., 2019), a deeper
78 understanding of people’s ‘mental maps’ of the role of EPs is still lacking.

79 A mental map denotes a visual representation of cognitive associations between
80 constructs (Bain et al., 2019), in our case how people relate each ecological program to
81 the achievement of each SDG, and these relationships can be different across people.
82 For example, the “Soil and Water Loss Control” program might be considered as
83 primarily contributing to SDGs linked to the health of the ecological environment and
84 human well-being or economic growth; or all three sustainability elements can be
85 equally evaluated. People’s mental maps of the role of EPs can show which SDGs are
86 considered as trade-offs or synergies. For example, if people believe that the

implementation of an ecological program creates a tension between promoting ecosystem restoration (SDG 15) and increasing resident income (SDG 8), this may discourage them from accepting and upscaling such restoration program (Liu et al., 2008) (and vice versa). Knowing the relationships between SDGs under the support of EPs can emphasize the rediscovery of the positive impacts of programs on these goals to highlight synergies and mitigate trade-offs.

The Tibetan Plateau—known as "the roof of the world", "the third pole on Earth" and "the water tower of Asia"—is an important ecological security barrier for China and the entire Asian continent (Teng et al., 2018). However, various issues related to the ecological environment, such as grassland degradation, biodiversity loss, and water and soil loss, have emerged on the Tibetan Plateau due to climate change and human disturbance (Sun et al., 2012; Ye et al., 2013; Yang et al., 2020; Hua et al., 2021). To ensure ecosystem health, the Chinese government has implemented a number of ecological protection and restoration plans (Liu et al., 2018; Sun et al., 2020). EPs have played a key role in SDGs, and have influenced how people perceive environmental, social, and economic sustainability. Due to the high vulnerability of the ecological environment of the Tibetan Plateau, and the high dependency of regional development on ecological resources (Liu, 2020; Xu et al., 2020), it is urgent to conduct more studies on the benefits of EPs in this region.

This study aims to identify the understanding of the potential role of EPs in contributing to SDGs, and thereby provide baseline information for the EPs'

communication model, and better planning of sustainability interventions to achieve multiple SDGs efficiently and effectively. We consulted personnel in relevant government departments through a survey on their perceptions of the contributions of nine EPs to SDG targets. The collected information was used to address the following questions: (1) what are the participants' perceptions of the contributions of EPs to the SDG targets?; (2) what are the participants' views on the synergies or trade-offs between SDGs supported by EPs, and how they vary among people?; and (3) how do participant demographics affect these perceptions?

2. Materials and methods

2.1. Study area

The Linzhi region (92°09′-98°47′ E, 26°52′-30°40′ N) is located southeast of the Tibetan Plateau (Fig. 1). It includes one district and six counties, covering an area of 116 175 km^2, and has an average altitude of 3100 m. The region is characterized by the coexistence of complex and diverse climate types (which comprise the tropical, subtropical, temperate, and cold climates); the annual average temperature is 8.7 °C, with a frost-free period of 180 days, and the annual average precipitation is approximately 650 mm, mainly falling in the growing season. The dominant vegetation in Linzhi is forest, which covers over 46% of the area.

The protection of the ecological environment is a priority here, as this region represents China's ecological security barrier. In Linzhi, the protection and construction

planning of ecological security barrier has been implemented to mitigate land degradation, strengthen the construction of natural reserves, and increase the socio-economic benefits. However, as protected areas account for about 36 % of Linzhi's land area, this region faces the challenge of balancing ecological protection and economic development (Zhao et al., 2020). Therefore, it was selected as a case study to evaluate the contributions of EPs to SDGs, and identify a way to optimize the programs' management in order to promote regional sustainable development.

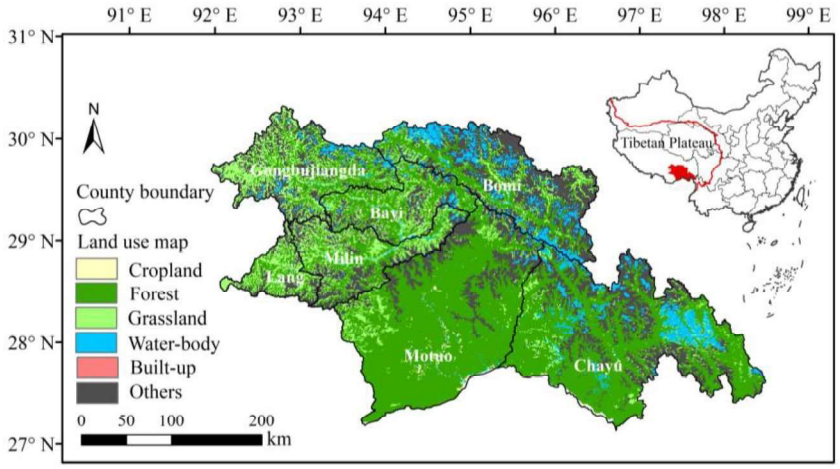


Fig. 1 Location and land use map of the study area in 2015. The land use data for this year was obtained from the Resource and Environment Science and Data Center (http://www.resdc.cn).

2.2. Questionnaire design and data collection

An anonymous questionnaire survey was conducted to evaluate the contributions of nine specific EPs toward the SDGs. The questionnaire consisted of two parts: 1) participants' demographics (gender, age, income level, department, and participation to ecological programs), and 2) assessment of the contribution of EPs to SDG targets using

143 a six-point scale (0, not at all; 1, very low; 2, low; 3, moderate; 4, high; 5, very high).
144 The most relevant SDG targets were chosen in the survey, while policy-oriented targets
145 and those that had no clear connection with ecological restoration were excluded (e.g.,
146 reducing the number of deaths and injuries from road traffic accidents, or ensuring all
147 girls and boys complete primary and secondary education; for the list of selected and
148 excluded targets, see SM1). Overall, 26 targets across 12 SDGs were considered (Table
149 1). EPs may contribute to the excluded SDG targets, but they were not evaluated here.
150 The nine EPs were sourced from the protection and construction planning of ecological
151 security barrier in Tibet (2008–2030) (Wang et al., 2017), all of which are ecological
152 protection and ecological construction projects (Table 2).

153 The survey was carried out in one district and six counties in Linzhi. The
154 questionnaire was distributed to relevant government departments from July 24th to
155 August 20th, 2019. Overall, 237 individuals participated, and 62 of them showed no
156 variability in value ratings for the contributions of EPs to SDG targets, indicating that
157 these participants may have rejected the identification of the role. Therefore, only the
158 responses provided by the remaining 175 participants were considered valid. The
159 questionnaire is included in the Supplementary Material (SM2).

160 **Table 1**

161 Sustainable development goals and targets evaluated in this study (for details on targets see SM1).

SDG title	Short label	Goal	Evaluated targets
 No Poverty	Poverty	End poverty in all its forms everywhere.	1.1, 1.5
		End hunger, achieve food security and improved nutrition,	

	Zero Hunger	Hunger	and promote sustainable agriculture.	2.3, 2.4
	Good Health & Well-Being	Health	Ensure healthy lives and promote wellbeing for all, at all ages.	3.9
	Quality Education	Education	Ensure inclusive and equitable quality education and lifelong learning opportunities for all.	
	Gender Equality	Gender	Achieve gender equality and empower all women and girls.	
	Clean Water & Sanitation	Water	Ensure availability and sustainable management of water and sanitation for all.	6.3, 6.4, 6.6
	Affordable & Clean Energy	Energy	Ensure access to affordable, reliable, sustainable and clean energy for all.	7.2
	Decent Work & Economic Growth	Growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all.	8.2, 8.4, 8.6
	Industry, Innovation & Infrastructure	Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.	9.1
	Reduced Inequalities	Equality	Reduce inequality in and among countries.	10.1, 10.4
	Sustainable Cities & Communities	Cities	Make cities and human settlements inclusive, safe, resilient, and sustainable.	11.5
	Responsible Consumption & Production	Consumption	Ensure sustainable consumption and production patterns.	12.2, 12.4, 12.5
	Climate Action	Climate	Take urgent action to combat climate change and its impacts.	13.1
	Life Below Water	Oceans	Conserve and sustainably use the oceans, seas, and marine resources.	
	Life on Land	Land	Protect, restore, and promote sustainable use of ecosystems, including managing forests, combating desertification,	15.1, 15.2, 15.3, 15.4, 15.5, 15.7

			reversing land degradation, and halting biodiversity loss.
	Peace, Justice & Strong Institutions	Peace	Promote peaceful and inclusive societies, including providing access to justice for all and building effective, accountable institutions.
	Partnerships for the Goals	Partnerships	Strengthen global efforts and partnerships to achieve sustainable development.

Table 2

The nine EPs in the survey were selected from the protection and construction planning of ecological security barrier in Tibet (2008–2030).

Program selected	Short label	Brief description of the program
Natural Grassland Protection	NGP	Treat degraded grassland by returning grazing to grassland and controlling rats, insects, and poisonous weeds. Returning grazing to grassland includes various components: grazing prohibition, rest grazing, rotational grazing, and grassland reseeding.
Forest Fire Prevention and Pest Control	FFPPC	Prevent forest fires and pests by establishing forest fire prevention centers, fire risk early warning and monitoring systems, and forest disease and insect control stations.
Wildlife Conservation and Nature Protection	WCNP	Protect important wild animals, plant species, and ecosystems; carry out scientific research, construct infrastructure, and support community development.
Wetland Conservation	WC	Protect and restore vegetation, and construct infrastructure and establish sustainable use demonstration area.
Traditional Energy Substitution — Agriculture and Pastoral Areas	TES	Increase the proportion of new clean energy use, reduce dependence on traditional biomass energy by strengthening the development of small hydropower, rural biogas, solar energy, and other energy.
Shelterbelt Construction	SC	Control the expansion of sandy land, mitigate soil erosion, and conserve water sources by establishing shelter forest systems.
Planting Grass and Natural Grassland Improvement	PGNGI	Artificial grass planting, and construction of grass seed breeding bases, forage industry demonstration bases, and irrigation facilities.
Sand Prevention and Control	SPC	Control land desertification and reduce wind erosion through the planting of trees and grass, enclosures, and checkerboard fences.

Soil and Water Loss Control	SWLC	Control soil erosion and improve the ecological environment through enclosures, afforestation, and grass planting, supplemented by small water and soil conservation supporting projects, such as check dams and canals.

2.3 Relationships between EPs and SDGs

2.3.1 Descriptive analysis

To evaluate the importance of EPs for the achievement of SDG targets, the average value of the contribution ratings of each ecological program to each target, given by all participants, was first calculated. Subsequently, the average values were normalized to a 0–1 range, and the results were divided into five levels (0–0.2, very low; 0.2–0.4, low; 0.4–0.6, moderate; 0.6–0.8, high; 0.8–1, very high). “Very low” and “low” were considered as “weak” contributions, “moderate” was considered as “moderate” contribution, and “very high” and “high” were considered as “strong” contributions.

2.3.2 Statistical analysis

To offer insights into the public perceptions, mental maps of the role of EPs in contributing to SDGs were identified, and it was also evaluated how they varied among people. The identification of these mental maps required the simultaneous analysis of three dimensions: participants, ecological programs, and SDGs (the rating of SDGs was obtained by averaging the rating of targets under each SDG given by each participant). For this analysis the three-mode principal component analysis (3MPCA) (Kroonenberg, 2008; Bain et al., 2019) was performed, using the N-way toolbox in MATLAB (Kiers, 2000) (for technical description see SM3 and SM4). This method shows systematic

patterns of the relationships between EPs and SDGs, and takes into account the different views of people. More specifically, we focused on the patterns of the relations between SDGs supported by programs. To understand who held different views within the mental maps, Spearman rank correlation analysis was used to find correlations between demographics and participant component scores (the basic outcomes of 3MPCA, which indicate to what degree the mental maps are relevant for the participants). Statistically significant correlations were considered at a $p < 0.05$.

3. Results

3.1 Perceived importance of ecological program-SDG target contributions

Survey participants did not evaluate all ecological program-SDG target (EP-T) contributions as equally important (Fig. 2), implying that there are differences in the potential role of EPs in achieving SDG targets. From a total of 234 EP-T combinations, 15 were perceived to have a "very high" importance and 71 to have a "high" importance for target attainment. Among these 86 EP-T combinations with strong contributions, "Soil and Water Loss Control", "Sand Prevention and Control", "Shelterbelt Construction", and "Wetland Conservation" were perceived as contributing to the largest number of distinct SDG targets (17, 13, 13, and 12 targets, respectively), closely followed by "Wildlife Conservation and Nature Protection" (11), and "Forest Fire Prevention and Pest Control" (9). Overall, many programs simultaneously aligned with

multiple SDGs, and, in particular, forestry EPs were considered to contribute more to the SDG targets.

For 20 of the 26 SDG targets evaluated, at least one ecological program was considered to contribute strongly to the achievement of the targets (Fig. 3a). Of the selected 12 SDGs in the survey, SDG 1 (Poverty), SDG 3 (Health), SDG 6 (Water) and SDG 15 (Land) were believed to receive the greatest contributions from different ecological programs, with 6, 8, 6 and 9 programs contributing to targets under each SDG, respectively (Fig. 3b). In addition, SDG 13 (Climate) and SDG 2 (Hunger) were also thought to receive relatively large contributions from the programs. These SDGs, which are linked to the health of the natural world and human well-being, were perceived to benefit the most from multiple ecological programs.

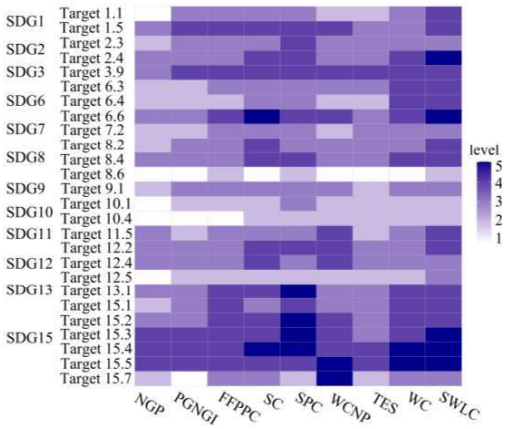
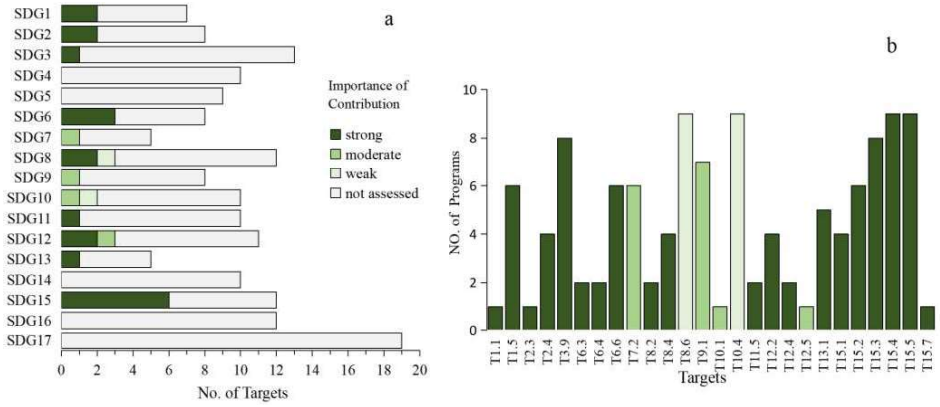


Fig. 2 Heat map of the perceived level of ecological program-target contributions. Acronyms: NGP, Natural Grassland Protection; PGNGI, Planting Grass and Natural Grassland Improvement; FFPPC, Forest Fire Prevention and Pest Control; SC, Shelterbelt Construction; SPC, Sand Prevention and Control; WCNP, Wildlife Conservation and Nature Protection; TES, Traditional Energy

218 Substitution; WC, Wetland Conservation; SWLC, Soil and Water Loss Control.



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220 **Fig. 3 a**) Number of targets per SDG for which the contribution of at least one ecological program
221 was rated as "strong", "moderate", or "weak", and **b**) Number of ecological programs rated as
222 "strong", "moderate", or "weak" per SDG target. "Not assessed" refers to SDG targets that were
223 excluded in the survey.

224 3.2 Perceptions of the relationships among SDGs supported by ecological programs

225 Three mental maps describing the relationships between EPs and SDGs were
226 identified (Supplementary Fig. S3), and they indicated that there was no single point of
227 view on EPs. However, the first mental map was dominant, accounting for 86% of the
228 total explained variation. While each mental map provided a considerable amount of
229 information, the focus was on the relationships among SDGs supported by EPs (Fig. 4)
230 (for the method used to identify relationships among SDGs see SM4).

231 The dominant mental map (Figs. S3a and S3b) showed that most EPs were seen
232 as contributing more to the achievement of SDG 1 (Poverty), SDG 2 (Hunger), SDG 3

(Health), SDG 6 (Water), SDG 13 (Climate), and SDG 15 (land); and were less relevant for SDG 8 (Growth), SDG 9 (Infrastructure), SDG 10 (Equality), SDG 11 (Cities) and SDG 12 (Consumption). That is, participants saw a primary trade-off between environmental/social and economic elements — more focus on the natural world and quality of life means less focus on sustained economic productivity (Figs. 4a and 4b). Furthermore, SDG synergy or trade-off pairs under the support of EPs were observed. Among them, SDG 1, SDG 2, SDG 3, and SDG 15 were ranked four times in the top-10 synergy pairs list, respectively (Fig. 5, left panel), and SDG 9–12 were ranked twice in the top-10 trade-off pairs list, respectively (Fig. 5, right panel). These results suggest that the contribution of EPs to most SDGs was considered to come at some cost to economic sustainability.

In the second mental map (Figs. S3c and S3d), participants thought that at least one ecological program was more focused on achieving all SDGs. Therefore, here synergies were mainly captured among environmental, social, and economic elements (Figs. 4c and 4d). Particularly, most EPs were conducive to the synergies of social and economic elements (e.g., synergies among SDG 1–12). In addition, trade-offs were detected between SDG 13/SDG15 and economic elements, but they represented only a minor component (Fig. 4d). The third mental map (Figs. S3e and S3f) showed that some programs were seen as focusing more on achieving SDG 9–15, illustrating that participants saw a primary synergy between environmental and economic elements (Fig. 4e). These results show that most EPs were perceived as targeting either both social and

254 economic elements, or both environmental and economic elements.

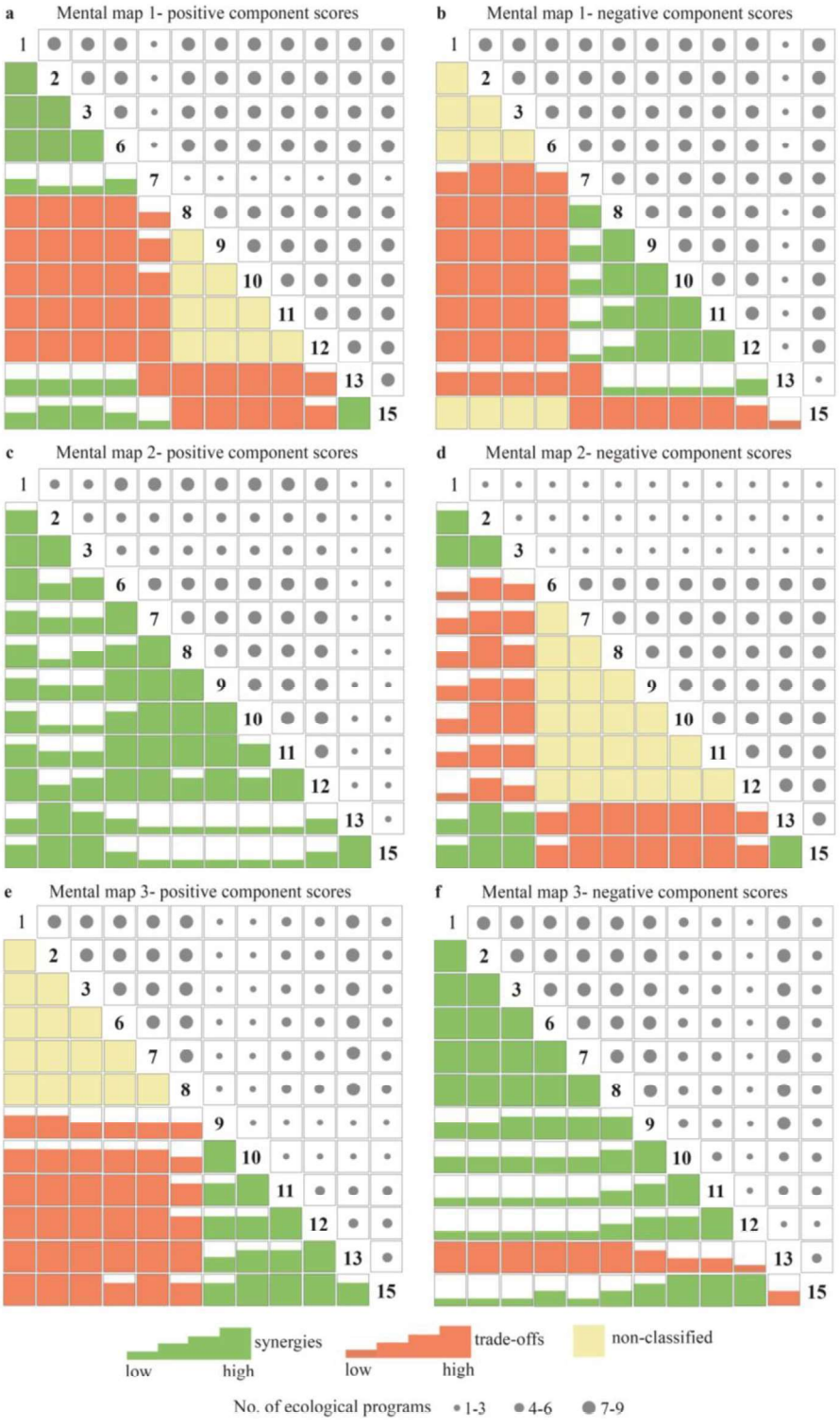

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Fig. 4 Synergies and trade-offs between SDGs under the support of ecological programs. The lower left corner represents synergies (green), trade-offs (orange), or non-classified data(yellow) observed among the SDGs, and the rectangular areas in each square cell indicate the degree of synergies or trade-offs for the SDG pairs. The upper right corner represents the number of EPs supporting SDG pairs (gray); SDGs are identified by the numbers in the diagonal. The mental map with positive scores indicates an above-average contribution rating of the programs toward the goals, while that with negative scores indicates a below-average contribution rating of the programs. The synergy between SDG 1 and SDG 2 in mental map 1 (with positive scores) illustrates that EPs contributed more strongly to achieving these two goals; the trade-off between SDG 8 and SDG 15 in mental map 1 (with positive/negative scores) indicates that EPs contributed more strongly to SDG 15 and more weakly to SDG 8; finally, the synergy between SDG 9 and SDG 10 in mental map 1 (with negative scores) shows that EPs contributed more weakly to achieving these two goals.

Fig. 5 Ranking of SDG synergy (left) and trade-off pairs (right) in mental map 1; SDG synergy pairs that received a relatively large support from EPs are given priority.

3.3 Correlations between participant component scores and demographics

In order to understand who specifically held different views within the mental maps illustrating the relationships among SDGs, Spearman rank correlation coefficients were obtained between each of three participant components and demographic

variables (Fig. 6). Results showed that the dominant mental map (conflict between environmental/social and economic elements) was held more strongly by older and higher-income people, and those who participated considerably in ecological programs. The second (social and economic elements coordination) and third (environmental and economic elements coordination) mental maps were strongly held by people who were not very involved with the programs and women, respectively.

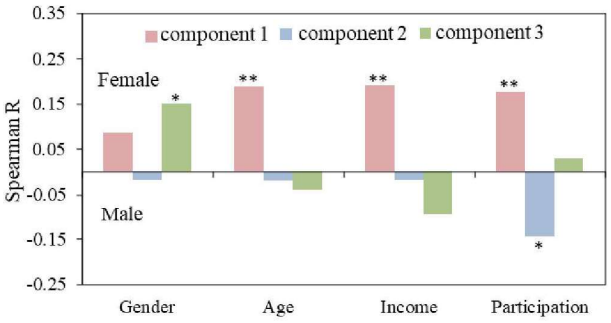

Fig. 6 Spearman correlation coefficients between participant component scores and demographics. Components 1, 2, and 3 represent the three participant components; demographics include participants' gender, age, income, and participation to EPs; * and ** indicate significant correlations at $p < 0.05$ and $p < 0.01$, respectively.

4. Discussion

4.1 Perceptions of ecological program-SDG target contributions

Understanding the contributions of EPs to SDGs is essential in order to effectively adjust priorities and improve land management (Bryan et al., 2018). In this study, the survey results identified which EPs were perceived to strongly contribute to the

297 attainment of 20 SDG targets. In particular, “Soil and Water Loss Control”, “Sand
298 Prevention and Control”, “Shelterbelt Construction”, and “Wetland Conservation”
299 were identified as key programs, each strongly contributing to more than 12 targets (Fig.
300 2). Based on local conditions, the EPs in the Linzhi region were more focused on
301 forestry, and directly contributed to the restoration of forest lands and water bodies.
302 Compared with other programs, these key programs produced relatively high
303 ecosystem service values in food and water supply, soil retention, wind prevention and
304 sand fixation, carbon storage, water conservation, and habitat quality (Vymazal et al.,
305 2011; Xie et al., 2017; Lu et al., 2018; Jiang et al., 2020). As a result, they made more
306 important contributions to multiple SDGs (Wood et al., 2018). However, the EPs that
307 were ranked lower should not be discounted, and more research is needed to determine
308 their contribution to the multiple aspects covered by the SDGs.

309 Among the goals, SDG 1, SDG 3, SDG 6, and SDG 15 were believed to receive
310 the greatest support from EPs (Figs. 2 and 3); and SDG 2 and SDG 13 were also thought
311 to receive relatively strong contributions. EPs increase biodiversity and improve the
312 ecological environment in the Tibetan Plateau (SDG 15) (Rey Benayas et al., 2009; Cai
313 et al., 2015; Hou et al., 2021; Zhang et al., 2021b). In addition, they ensure the
314 performance of ecosystem functions related to climate (SDG 13) and water (SDG 6),
315 such as carbon storage, water quality control, and water storage (Xiang et al., 2016;
316 Griscom et al., 2017; Lu et al., 2018; Lian et al., 2020). At the same time, local residents
317 can use ecological resources to increase their income (SDG 1 and SDG 2) (Abdullah et

al., 2016; Huang et al., 2018). EPs can also improve people's health (SDG 3), as in the case of restoration and afforestation for sand fixation, which cause a reduction in harmful dust storms (Kang et al., 2016). Bryan et al. (2018) mapped the investment of China's 16 major land programs toward SDGs, and showed that most investment contributed to SDG 15, SDG 2, and SDG 1. In addition, the study also suggested that SDG 13, SDG 11, SDG 10, SDG6, and SDG 8 also benefited more from the programs. Compared with the results of program assessments in the entire China, the design of EPs in Linzhi was perceived as focusing more on environmental health and life quality. This shows that the current ecological planning does not yet adequately support the achievement of SDGs.

4.2 Mental maps of the relationships among SDGs supported by ecological programs

The relationships among SDGs were represented by three mental maps. This indicated that managers should have a broader and deeper understanding of those EPs that aim to implement multifaceted strategies (Costanza, 2012; Mitsch, 2012; Wortley et al., 2013). In the present study, for a high proportion of participants, there was a primary trade-off between environmental/social and economic elements. The trade-offs observed here are in line with some expert models that contrast economic and environmental of sustainability (Waas et al., 2011; Nilsson et al., 2016; Pradhan et al., 2017). EPs may result in lock-in effects, where promoting one SDG may limit the achievement of others. To mitigate such effects, complementary programs or multiple policies are required. For example, the "Natural Grassland Protection" program for

339 returning grazing to grassland might lead to unintended consequences, such as
340 unemployment and increased production costs. However, these tensions could be
341 skillfully managed via complementary programs, or policies aimed at increasing
342 income and creating jobs. Policies that minimize trade-offs with SDG 8–SDG12 have
343 been suggested to be the most effective.

344 The synergies observed can be clearly connected to ecological programs. For
345 example, SDG 15 and SDG 13 presented a highly synergistic state, illustrating that
346 these land practices safeguard habitat and biological diversity, and enhance climate
347 resilience (Griscom et al., 2017; Smith et al., 2020; Yao et al., 2021). Pradhan et al.
348 (2017) indicated that SDG 15 has trade-offs with other goals. However, synergies
349 between SDG 15 and the other SDGs linked to human well-being were found in this
350 study, and results indicate that bringing the role of EPs into the framework of SDGs
351 provides an opportunity for pursuing synergies between SDGs.

352 The present study also found that a small number of participants believed that
353 some EPs have provided opportunities for synergistic social and economic elements, or
354 environmental and economic elements. Zhen et al. (2018) showed that different
355 approaches adopted by local residents to manage the same ecological program will
356 produce different benefits in the Tibetan Plateau, and that an environmental and
357 economic “win-win” situation is possible when appropriate management practices are
358 adopted. People’s perception of sustainability reflects the implementation of ecological
359 programs, the communication among people holding different mental maps may

360 contribute to the understanding of how EPs further promote multiple SDGs and break
361 the lock-in effects. For example, sharing and communicating the role of EPs could
362 highlight how they address land degradation, help to develop ecology-related industries,
363 and improve human well-being. This study also provided supplementary evidence for
364 the economic and social benefits of EPs, showing that focusing on ecological
365 environment outcomes can be as effective as focusing on the social or economic
366 impacts of these programs (Nielsen-Pincus and Moseley, 2013; Sheng et al., 2019;
367 McElwee et al., 2020).

368 The dominant mental map was held more strongly by older and higher-income
369 people, and those who participated considerably in ecological programs. These people
370 may have been engaged in such programs for a long time, and their assessments of the
371 contributions toward the goals may be more experienced (Sapp et al., 2013). The second
372 and third mental maps were held more strongly by people with low participation in
373 programs and women, respectively. Their evaluations of the contributions may be more
374 consistent with their own beliefs (Sapp et al., 2013). As people with different
375 experiences and beliefs hold different perceptions of the role of EPs, understanding
376 their mental maps and identifying which information is widely accepted, provides the
377 possibility to achieve resonance among different people. Therefore, it is recommended
378 to use the dominant mental map as a policy guide and communication model for
379 ecological programs, as it can contribute to improving people's engagement with
380 ecological sustainability management, and to gaining the widest support to promote

ecological restoration and sustainable development.

4.3 Ecological program-based management for SDG synergies

A key aim of China's EPs is to jointly solve systemic socio-economic and environmental issues (Liu et al., 2007). An ecological program-based approach provides opportunities to capture synergies between SDGs. The present study considered ecological program-based management based on three aspects: priority adjustment, integrated portfolio, and stakeholder engagement. Priority adjustment puts an emphasis on giving priority to cost-effective ecological programs, and priorities are constantly adapted over time. In the Linzhi region, "Soil and Water Loss Control", "Sand Prevention and Control", "Shelterbelt Construction", and "Wetland Conservation" should be given priority. Programs should also consider local suitability, selecting appropriate project sites, species, and ecosystems to adapt to climate change and other disturbances (Ghestem et al., 2014). The integrated portfolio aspect refers to the fact that EPs contribute to multiple SDGs through a multi-pronged policy instrument. In this study, it was recognized that the program-based management alone was insufficient to achieve all SDGs in Linzhi, and that EPs will need to be complemented by laws and socio-economic initiatives on minimizing trade-offs with SDG8–SDG12. The third aspect, stakeholder engagement, highlights the fact that people with different experiences and beliefs engage in, and communicate, EPs to share management approaches and identify potential solutions for SDGs synergies.

5. Conclusion

The survey results reflected the broad supporting role of EPs in meeting SDGs. Although we were unable to evaluate the contributions of EPs to all SDG targets, a number of programs, including "Soil and Water Loss Control", "Sand Prevention and Control", "Shelterbelt Construction", and "Wetland Conservation", were identified as important for the achievement of more than 12 SDG targets in Linzhi. Furthermore, three mental maps of how EPs and SDGs are related were identified. The dominant map illustrated the trade-offs between environmental/social and economic sustainability supported by EPs, while the other two maps identified primary synergies between economic and social/environmental sustainability. It is here recommended to use the dominant mental map as a guide for communicating the role of EPs in Linzhi. By clarifying the role of EPs, we help chart a direction for the consideration of ecological program-based management into local sustainable development plans.

This study provides a regional empirical analysis of the role of EPs under the framework of UN SDGs. However, we are aware that there are limitations in terms of survey sampling, and this research would benefit from responses of other typical areas and different stakeholder groups over the Tibetan Plateau. Future research will combine participant perception with biophysical and socioeconomic indicators, and will integrate them into the evaluation model for quantitative research to track and predict the effects of ecological protection and restoration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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