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Smart-Valleys' Effects on Inland Valleys Ecosystem Services: Farmer Insights in West Africa's Sudano-Guinean Zones

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1. Introduction

Inland valleys are freshwater wetlands located in low-lying areas and regions bordering rivers. Spanning approximately 85 million hectares across Sub-Saharan Africa, they play a vital role in the well-being of local populations through the diverse ecosystem services they provide (Dossou-Yovo et al. 2017). As sediment and nutrient rich environments that remain nearly wet year-round, these valleys are the primary agricultural reservoirs in West Africa, supporting alternating rice cultivation and associated crops, such as maize, tubers, and other agricultural products, during the dry season.

Considering current food security challenges such as the 300 million people suffering from hunger in Africa in 2023 (Djagba et al., 2019) due to rapid population growth, diminishing agricultural land, and erratic rainfall, inland valleys have become essential resources for the majority of farmers, agricultural research institutions, and development projects. Consequently, various water management strategies have been applied to enhance agricultural productivity in these valleys, including *Bund valley* (dike-based approaches) and the more recent participatory method known as *Smart valley*, introduced by the Africa Rice Center in West Africa. However, the performance of these approaches in meeting farmers' needs while maintaining ecosystem services and enhancing food production has been underexplored in the region.

Many of the inland valley management approaches developed since the 1970s have been abandoned by smallholder farmers due to dissatisfaction with the expected services (Yacouba et al. 2019). Understanding the factors that influence smallholder farmers' satisfaction is therefore key for the sustainable adoption of inland valley management approaches and ecological compensation policies (Pang et al. 2022). Assessing how current inland valley management approaches contribute to both smallholder farmers' satisfaction with ecosystem services and the sustainability of these ecosystems could inform policy making in inland valley management.

This study adopts a socioeconomic perspective to evaluate the effects of inland valley development approaches on ecosystem services.

2. Material and Methods

Study Area: This study was conducted in the Sudanian-Guinean zone of Benin, specifically in 21 inland valleys selected within the commune of Savalou. Covering an area of 2,674.00 km², Savalou is one of the communes in the Collines Department, known for its extensive use of rainfed inland valleys for rice cultivation.

Data Collection**:** A mixed-method socioeconomic approach, combining both quantitative and qualitative data, was used between July and October 2022. The study began with a literature review on ecosystem services and inland valley management, followed by a preliminary survey of 16 key informants (including officials from the National Lowland Office of Benin and local leaders). Next, 21 focus group discussions (10 with women and 11 with men) were conducted to gather insights about local perceptions of ecosystem services. These discussions informed the design of a baseline questionnaire used in semi-structured interviews with 158 participants across 21 inland valleys in Savalou. The interviews focused on management approaches, satisfaction with ecosystem services, and perceived threats, with satisfaction and threat importance rated on a 5-point Likert scale.

Data Analysis: The consulted documents and articles were synthesized and triangulated to understand inland valley management approaches in West Africa and the ecosystem services provided by them. The Relative Importance Index (RII) (Equation 1) was calculated to assess perceived satisfaction with ecosystem services, sub-services, and threats to inland valleys sustainability. Key sub-services were compared across management approaches. A binomial logistic model was used to analyze the impact of socioeconomic factors on ecosystem service satisfaction, accounting for overdispersion with a quasi-binomial structure. All analyses were performed using R (R Core Team, 2023).

$$\mathrm{RII} = \frac{\sum_i^n W_i}{A \times N} \qquad (Eq.1)$$

with W_i is the score given by respondent *I*, ranging from 1 to 5, *A* is the highest score (5 in this study), and *N* is the total number of respondents.

3. Results and Discussion

The findings in Table 1 show that the Smart valley approach had the highest rank for provisioning (0.89) and regulating services (0.89), particularly in terms of food, fresh water, and water regulation (0.83), while the Undeveloped valley had the highest ranks satisfaction for medicinal products (0.67), as well as cultural services, especially sacralized sites (0.54). These results highlight the trade-offs between water management and some of the ecosystem services provided by inland valleys. Previous studies showed that Smart valley approach improved water management by reducing the impacts of drought and flooding on agricultural productivity, which contributed to explain the higher ranks of provisioning and regulating ecosystem services provided by farmers (Dossou-Yovo et al., 2022). However, the Smart-Valleys approach resulted in lower cultural ecosystem services when compared to undeveloped inland valleys. This result implies the need to integrate the cultural ecosystem services in designing and implementing the Smart-Valleys approach as suggested by previous authors (Rodenburg et al., 2014 and Djagba et al., 2019).

Table 1. Ecosystem Services (ES) Satisfaction Across Different Valley Types Based on RII

Key Sub services	RII	Smart valley	Bund Valley	Undeveloped valley
Provisioning ES		**0.89**	**0.78**	**0.57**
Food	0.70	0.80	0.65	0.54
Freshwater	0.69	0.70	0.54	0.43
Medicines	0.63	0.33	0.22	0.67
Regulating ES		**0.89**	**0.66**	**0.57**
Water regulation	0.64	0.83	0.64	0.45

Pests regulation	0.60	0.46	0.57	0.66
Microclimate regulation	0.56	0.33	0.27	0.72
Supporting ES		**0.66**	**0.53**	**0.42**
Nutrients cycle	0.53	0.63	0.50	0.43
Primary production	0.48	0.53	0.43	0.33
Soil formation	0.47	0.34	0.34	0.23
Cultural ES		**0.12**	**0.21**	**0.54**
Sacralized site	0.34	0.34	0.32	0.54
Social relation (Yam festival)	0.22	0.54	0.44	0.33
Education	0.15	0.21	0.21	0.23

The binomial logistic regression results highlight the socio-economic factors influencing satisfaction with perceived ecosystem services (ES). The key variables include gender, education, religion, income, main activity, and management approach. Significant determinants vary across different ES categories: higher income levels, secondary education, and women positively affect provisioning and regulating services satisfaction, while men and religion notably influence cultural services. The Smart valley management has a strong positive impact on regulating services, whereas the Undeveloped valley negatively affects provisioning services but boosts cultural ES satisfaction. Standard errors are reported in brackets. Notably, it has been observed that women express greater satisfaction with provisioning services, likely due to the variety of services (such as food, water, firewood, etc.) they derive from the ecosystem, compared to men. Mensah et al. (2017) argue that this positive sentiment results from both a sense of duty within the household and the close relationship women maintain with the resources of these ecosystems.

Threats to inland valleys

Figure 2 illustrates the perceived importance of various threats across the management approaches (Bund, Smart, and Undeveloped) using the Relative Importance Index (RII). The Bund valley reports the highest perceived threat, especially from heavy fertilizer use, while the Smart Valley expresses significant concern over sedimentation. The Undeveloped valley predominantly faces threats related to hydrological constraints, such as floods, droughts, and risks from chemical fertilizer pollution. This underscores how each valley approach prioritizes different challenges based on their specific management practices and ecological conditions. These findings are consistent with studies that identify pollution in waterways near agricultural inland valleys, particularly from nitrates, phosphorus, pesticides, salt, and pathogens (Djagba et al., 2019; Mengistie et al., 2017). The impact of this pollution is considerable on nearby biological resources due to the interconnectedness of water systems, their resources, and the adjacent interior valleys.

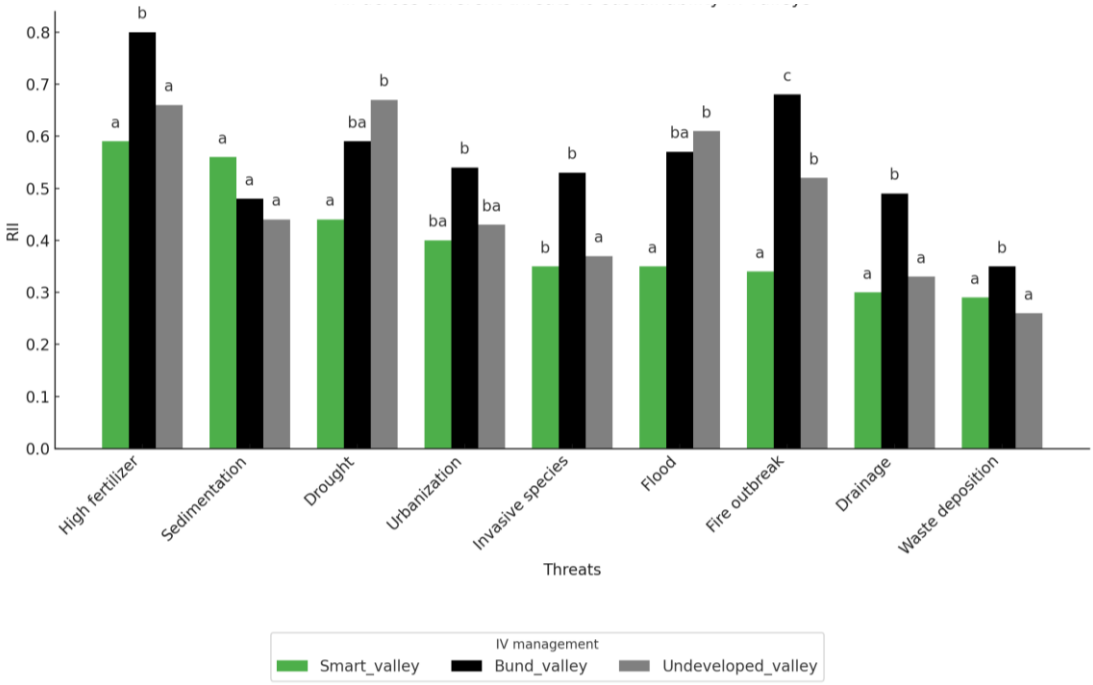

Figure 2. Perceived threats to inland valley sustainability for each management approach *(a–c: Relative Importance Index values followed by different letters are different at Bonferroni-adjusted significant level (post-hoc tests with Bonferroni's correction for multiple comparisons)).*

4. Conclusions and Outlook

This study emphasizes the need to integrate smallholder farmers' agricultural priorities with the conservation of ecosystem services to ensure the long-term sustainability of ecosystems. The success of management approaches, such as the Smart valley approach, relies on addressing provisioning and regulating services while mitigating perceived threats to the sustainability of inland valleys. Two key implications arise: (1) the necessity of adopting management approaches that balance agricultural needs with the conservation of diverse ecosystem services, and (2) the importance of considering socio-economic and cultural factors, particularly the vital role women play in natural resource management when developing policies and strategies.

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