Landscape Architecture

ARTICLE

Livelihood-Sensitive Hydrological Indexing of Nature-Based Flood Adaptation Priorities in Nigerian Land-Use Planning

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Abstract

Flood adaptation in land use in Nigeria calls for an intervention order that aligns with the level of flood burden, exposure of livelihood activities, and deterioration in land cover. In this paper, four flood-exposed communities; Odekpe, Umunakwo, Oko, and Okwe have been analyzed using the 198-respondent dataset on livelihood activity, size of farmland, flood shock index, nature-based integration value, and land cover type. About 61.1% of all respondents experienced severe to very severe flood shock, 72.7% of respondents earn their livelihood through farming and fishing, and 63.6% of respondent are exposed to small to medium-size farms. Odekpe had the largest flood shock value of 0.703, followed by Umunakwo (0.665), Oko (0.648), and Okwe (0.574). During 1990-2020, built-up and bare lands increased from 14.93 to 96.59 km^2 whereas floodplains area increased from 183.07 to 332.73 km^2. Vegetation and water bodies have declined during this period. The highest priority scores were allocated for ecosystem restoration and protection (27.51), green infrastructure development (25.01), and sustainable agriculture (24.80).

Keywords: nature-based solutions; flood adaptation; land-use planning; Nigeria; livelihood exposure; hydrological index; climate justice

1. Introduction

Flood adaptation in riverine and peri-urban land-use systems is no longer a simple question of the capacity for drainage. It also involves the state of vegetation cover, wetlands, floodplains, water bodies, cropland, informal settlement, and local institutions determining how landscapes are either conserved or developed. Nature-based solutions are increasingly significant due to their reliance on natural ecosystem services to manage water storage, slowing, infiltration, and filtration, as well as promoting biological diversity, recreational space, soil stabilization, and livelihood sustainability [3, 6, 17]. However, their effectiveness in flood-prone areas lies in their choice based on local vulnerability to the hazard, rather than as part of generic greening policies.

Received: 18 September 2024; Revised: 21 December 2024; Accepted: 20 March 2025; Published: 30 June 2025.

doi: 10.70517/la20251152-03

This is highlighted by the nature of the Nigerian land-use system being considered here. The impacts of flooding can include damage to settlements, farmland, access corridors, market locations, fishing operations, and community mobility. Changes in land cover can exacerbate those effects through the loss of vegetation cover, reduction of water body extent, increased floodplain exposure, and higher proportions of built-up and bare lands. Wetland conservation can help lower peak flows; however, it will not necessarily solve problems related to agricultural exposure. Improved green infrastructure may help with local drainage issues; nevertheless, it will be insufficient if settlement growth persists with no room for infiltration.

Figure 1. Floodplain evidence.

Finally, the inclusion of social vulnerability adds yet another rationale for prioritisation based on specific interventions. Vulnerability is a product of exposure to hazard, income, land ownership, infrastructure, recognition, and power to influence planning decisions [4, 11, 16]. Flood policies that protect physical structures while neglecting farmers, fishermen, and small holders would reduce visibility of inundations, but leave livelihood vulnerabilities unaddressed. This argument holds true more broadly according to social vulnerability literature, which states that environmental hazards affect people differently depending on social standing, institution protection, and resource availability [4, 19]. Thus, flood adaptation policies require a process of assessing hydrological burden and livelihood exposure together.

This paper defines which ecological flood-adaptation interventions are most urgent for institutional strengthening in light of community flood shock, land-water livelihoods, farm-size exposure, and three-decade land-cover change.

The analysis does not promote the use of all ecological measures for flood mitigation. Instead, it ranks eleven named interventions based on the number of communities, integration ratings, and area covered by land cover types from 1990 to 2020.

The numerical data set contains Odekpe, Umunakwo, Oko, and Okwe, with 198 respondents, five categories of flood shock by community, distributions of occupations and farms sizes, integration ratings of eleven nature-based interventions, and land covers areas of water bodies, floodplain, vegetation, and built-up/bare lands from 1990 to 2020 [8]. These numbers denote flood-exposed livelihood groups, flood burden at community level, land cover transition, and poorly integrated interventions.

In turn, the photogenic summary of the study area in Figure 1 illustrates land-water livelihood, farm-size distribution, land-cover transition, and intervention priorities in the context of flood risk.

The five photogenic images clarify why the calculation relies on community flood-shock, livelihood distribution, and land-cover change. The community flood values will constitute the hydrological component, the distribution values – the livelihood component, while land cover transition explains the necessity of addressing the restoration, green infrastructure, agriculture, and erosion control interventions.

2. Literature Review

2.1. Nature-based flood adaptations in changing land cover

Ecological interventions used for mitigating flood events rely on ecological functions that can impact water storage and distribution. Wetlands and floodplains absorb excessive water and reduce peak flow; vegetation retains moisture, stabilizes shorelines, and promotes water infiltration; riparian buffer zones reduce bank erosion; and urban green infrastructure intercepts runoff [5, 9, 15]. These functions become critical under increasing built-up expansion and inadequate drainage system due to climate changes.

However, the literature is cautious when referring to nature-based solutions as a universal remedy against floods. Seddon et al. [17] argue that ecological measures need to be properly designed, socially and environmentally legitimized, and integrated within the local environment. Frantzeskaki et al. [10] explain how their successful implementation requires interaction between science, planning, and practitioner communities. Hobbie and Grimm [12] highlight the role of urban ecosystems in adaptation, while acknowledging their dependence on local land cover, maintenance, and governance. Thus, the prioritization of nature-based interventions in the proposed paper is justified.

At the same time, the literature suggests that uncertainty and institutional confidence play an important role in the promotion of nature-based solutions. According to Thorne et al. [18], uncertainty about effectiveness, acceptability, and implementation limits the widespread adoption of blue-green infrastructure. Ahern [2] recommends using resilient design and multifunctional landscapes capable of adaptation. Guidelines for flood risk mitigation propose the use of integrated plans and multiple protective structures [2, 13, 18]. The proposed calculation prioritizes the most reliable hydrological measures while ranking weak interventions by importance.

2.2. Flood risk and livelihood sensitivities

Flood vulnerability in African cities and peri-urban areas is associated with low socio-economic status, poor living conditions, lack of infrastructure, insecurity of tenure, and insufficient institutional protection. In particular, Douglas et al. [7] view floods in urban areas of Africa as social and environmental injustices. Adelekan [1] notes that vulnerability in coastal communities of Lagos results from their exposure to floods, services, coping

 doi: 10.70517/la20251152-03

capabilities, and governance arrangements. These studies are relevant to the current study since they illustrate how vulnerability emerges out of complex interactions of water, land cover, infrastructure, and social factors.

The four Nigerian communities discussed in the paper also demonstrate the importance of land-water livelihoods. Agricultural labour constitutes 49.0% of the total occupations while 23.7% of the total work in fishing. Medium and large-size farms account for 63.6% of the farm-size exposures. Such statistics indicate that the success of adaptation depends on the protection of livelihoods. The loss of crops or fishing spots means that adaptation is ineffective even if it reduces the number of flooded drains.

The issue can be discussed within the conceptual framework of environmental justice. First, environmental justice transcends distribution and includes considerations of recognition and redress [16]. Second, Cutter et al. [4] reveal how social inequalities produce hazard outcomes. Finally, Friend and Moench [11] advocate for the inclusion of poverty in resilience policies. Thus, priority adaptation interventions can be defined as those combining high flood burden and livelihood vulnerability with weak institutional integration.

2.3. Prioritizing interventions in land-use practice

Land-use planning recognizes nature-based interventions as a category; however, eleven different measures vary in institutional strength and relevance to livelihoods. Examples of these interventions include development of green infrastructure, ecosystem restoration and protection, natural flood retention and restoration, sustainable urban planning with green spaces, restoration and afforestation, wetland conservation, sustainable agricultural practices, use of natural barriers, limited use of native species, aquifer recharge and water retention management, and erosion control through vegetation. These measures are uneven in institutional visibility and relevance to farming, fishing, vegetation loss, and urbanization. However, the indexing calculation produces a consistent order from the available data.

The calculation does not substitute the participatory mapping, hydrological modeling, cost assessment, and engineering designs used for developing flood adaptation policies. However, when modeling and technical assessments are not yet available, the calculation enables the assessment of intervention priorities based on data on the number of communities, integration ratings, and land cover transitions.

3. Material and Methods

3.1. Data

The data include four sets of aggregated values. The first set contains information on 198 respondents in terms of occupation and farm size. The second set provides information on flood shock responses recorded for Odekpe, Umunakwo, Oko, and Okwe across five ordinal categories. The third set includes information on the integration rating of eleven nature-based interventions: green infrastructure development; ecosystem restoration and protection; natural flood retention and restoration; sustainable urban planning with green space; restoration and afforestation; wetland conservation; sustainable agricultural practices; use of natural barriers; limited use of native species; aquifer recharge and water-retention management; and erosion control through vegetation. The last set describes the changes in land covers of water bodies, floodplains, vegetation, and built-up/bare land from 1990 to 2020.

Thus, the analysis relies on aggregate data and does not attempt to define whether a certain farm or fishing household has been more impacted by the flood. It also does not explore land cover change around each of the settlements separately.

3.2. Flood-shock and livelihood calculation

Flood-shock categories were assigned ordinal weights from zero to four. Highly insignificant responses received zero and highly significant responses received four. For community c, the flood-shock index H_c was calculated as

$$H_c = \frac{{}^{4}_{k=0}\, w_k n_{ck}}{4N_c}, \tag{1}$$

where w_k is the ordinal weight, n_{ck} is the number of responses in category k, and N_c is the community sample size. The denominator places the result on a zero-to-one scale.

This transformation gives meaning to the full response distribution instead of counting only the top categories. A community with many moderate responses and a community with many highly significant responses are not treated as equivalent. The resulting values are therefore more informative for planning than a simple affected/not-affected count.

Livelihood sensitivity was calculated from two shares. Direct land-water dependence was

$$L_d = \frac{N_{\text{farming}} \;\; N_{\text{fishing}}}{N}, \tag{2}$$

and farm-size exposure was

$$L_f = \frac{N_{\text{small farm}} \;\; N_{\text{medium farm}}}{N}. \tag{3}$$

The combined livelihood-sensitivity value was

$$L_s = 0.5L_d \;\; 0.5L_f. \tag{4}$$

Equal weighting is retained because the tabulated record does not cross-classify occupation by farm size or community. The value should be read as a planning summary of land-water dependence, not as a household risk estimate.

3.3. Integration and priority calculation

Each nature-based practice a was assigned an integration value I_a using the five reported integration levels. Not integrated, slightly integrated, neutral, moderately integrated, and highly integrated responses were weighted as zero, one, two, three, and four. The intervention-integration value was calculated as

$$I_a = \frac{p_{a1} \;\; 2p_{a2} \;\; 3p_{a3} \;\; 4p_{a4}}{400}, \tag{5}$$

where p_{a1} to p_{a4} are the percentage shares for slightly integrated through highly integrated responses. The not-integrated share contributes zero, and the result is scaled between zero and one.

Two companion shares help interpret the distribution. The low-integration share was calculated as

$$Q_a = \frac{p_{\text{not},a} \;\; p_{\text{slight},a}}{100}, \tag{6}$$

and the advanced-integration share was calculated as

$$A_a = \frac{p_{\text{moderate},a} \;\; p_{\text{high},a}}{100}. \tag{7}$$

These shares show whether low integration is caused by a large not-integrated response, a large slightly integrated response, or both. They also show whether a practice already has a meaningful moderate/high base.

The priority value links weak integration with flood and livelihood exposure:

$$R_a = 1 - I_a \bar{H} L_s \times 100. \tag{8}$$

A high value identifies a practice whose weak integration is serious in a setting with substantial flood burden and land-water livelihood exposure. The value does not claim that the practice alone will remove flood risk. It shows where planning institutions should concentrate early effort.

3.4. Moderate-integration recalculation

The calculation also evaluates a limited strengthening step for the three weakest integration values. A share r of the not-integrated responses is moved into the moderately integrated category while other response shares remain unchanged:

$$I_a r = I_a \ \frac{3 r p_{\mathrm{not},a}}{400}. \tag{9}$$

The values $r = 0.25$ and $r = 0.50$ are retained. They do not represent new interventions or new field observations. They show how far the weakest categories move when a defined portion of non-integration becomes moderate integration.

The visual sequence in Figure 2 shows the evidence components used in the calculation without mathematical notation. The panels correspond to community flood burden, livelihood and farm-size exposure, intervention integration, and the resulting priority order.

Figure 2. Calculation inputs.

The analytical significance of the components within Figure 2 lies in associating each numeric element with the corresponding land use condition. The priority value was obtained from the community's flood shock, livelihoods from land and water, integration status, and the gap between current and early planned integration.

4. Results

4.1. Livelihood exposure of the respondents

The respondent characteristics are marked by the direct relationship between the respondent livelihood and land and water. Among the 198 respondents, 97 of them (49.0%) were farmers. There were 47 fishermen (23.7%). The sum of fishermen and farmers constitutes 144 people (72.7% of the sample). The result emphasizes the indivisible connection of flood adaptation and livelihood protection since soil stability, reliable water sources, safety in farms, and floodplains are factors that influence respondents' predominant occupation.

Farm size is an additional proof of the point discussed above. Small-scale farms (less than 0.5 ha) constitute 44 respondents (22.2%). Medium-scale farms (0.5–1 ha) are represented by 82 people (41.4%), which means that 126 of 198 people (63.6%) run small or medium farms. On the other hand, there are 72 respondents (36.4%) who own large-scale farms (more than 1 ha). Since small and medium farms have limited land resources, flood consequences can easily turn into soil and crop damage.

Table 1. Respondent exposure profile.

Indicator	Count	Share (%)
Small farm ($<$ 0.5 ha)	44	22.2
Medium farm (0.5–1 ha)	82	41.4
Large farm ($>$ 1 ha)	72	36.4
Fishing	47	23.7
Farming	97	49.0
Craftsmanship/self-employed	11	5.6
Other livelihood category	7	3.5
Civil servant	10	5.1
Mixed livelihood	17	8.6
Trading	9	4.5
Farming plus fishing	144	72.7
Small plus medium farms	126	63.6

These values clearly warrant the livelihood sensitivity aspect of the flood adaptation index since any plan solely focused on drainage channels would ignore the fact that three-quarters of the survey respondents rely on farming and fishing as means of earning their livelihood, while almost two-thirds are small to medium farm exposure related. Hence, there is a broader implication in terms of flood adaptation which encompasses crop sustainability, accessibility to water resources, soil protection, and security of community livelihoods.

4.2. Community flood-shock distribution

Responses to flood shock are clustered towards the high end of the ordinal scale. Highly and significantly shocked individuals form the majority of responses with 121 of 198 people, or 61.1%. Overall flood-shock distribution is 0.649, or $\bar{H}$=0.649, confirming the significance of flood disturbances among the sampled 198 respondents.

The highest value for flood-shock distribution is recorded by Odekpe at 0.703. Similarly, it reports the highest percentage of severely shocked individuals, at 36 out of 53 respondents, or 67.9%. Second on the scale is Umunakwo with 0.665 flood-shock distribution, while the third position is shared by Oko with the same level of flood shock

(0.648), though Okwe has the lowest level of flood-shock distribution at 0.574. However, the severity of responses is similar for all communities in question, with 48.9% being shocked significantly or highly.

Table 2. Community flood-shock values.

Community	Sample	Significant + highly significant	Severe share (%)	Flood-shock index
Odekpe	53	36	67.9	0.703
Umunakwo	44	29	65.9	0.665
Oko	54	33	61.1	0.648
Okwe	47	23	48.9	0.574
Total	198	121	61.1	0.649

The community values require sequencing rather than exclusion. Odekpe and Umunakwo warrant earlier attention because they combine the highest index values with the highest severe-response shares. Oko should remain in the central intervention corridor because its index almost matches the overall value. Okwe should not be treated as low concern; nearly one half of respondents there still report severe flood shock.

The burden profile in Figure 3 places these differences in a single visual comparison. The figure is useful because the absolute sample size, severe-response share, and flood-shock index can be read together instead of in separate statements.

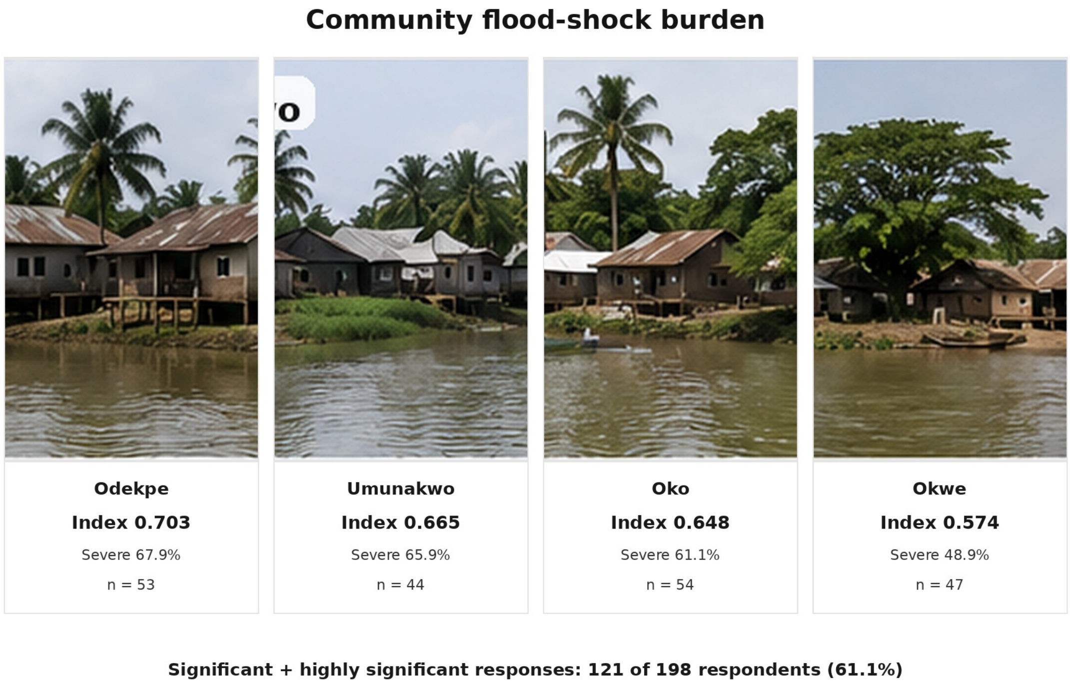

Figure 3. Flood-shock burden.

This pattern suggests a community-specific implementation schedule that takes into account each of the four communities. An approach that assumes a single-community intervention will understate the disparity between Odekpe and the three other communities. On the other hand, a strategy for all communities at once will overstate the higher burden in Odekpe and Umunakwo. The best solution is therefore to start with the communities experiencing a relatively greater burden.

4.3. Land cover change

The land-cover series shows that there has been considerable reclassification of the ecological setting relevant to flood adaptation. The total extent of built-up land and bare areas went up from 14.93 km^2 in 1990 to 96.59 km^2 in 2020, an increase of 81.66 km^2 or 546.9% in relative terms. This is the greatest proportional increase among the land cover types. This kind of increase could impede natural drainage through infiltration, increase surface runoff, degrade vegetated buffer zones, and reduce infiltration rates.

The floodplain area expanded from 183.07 to 332.73 km^2, an increase of 149.66 km^2 or 81.8%. This growth is very important for understanding how floods affect the area in question because floodplain planning should necessarily involve issues of floodplain planning, agriculture, and settlement management.

Vegetation coverage fell from 427.59 to 253.01 km^2, a loss of 174.58 km^2 or 40.8%. Coverage of water bodies fell from 93.95 to 37.19 km^2, a decrease of 56.76 km^2 or 60.4%. These reductions represent the two greatest losses in ecological value of the land covers considered, although the former represents a larger absolute loss.

Table 3. Land-cover change.

Land-cover class	1990	2000	2010	2020	Change 1990–2020 (%)
Water body	93.95	102.12	38.50	37.19	-60.4
Floodplain	183.07	302.93	294.14	332.73	81.8
Vegetation	427.59	283.32	293.19	253.01	-40.8
Built-up/bare land	14.93	31.06	93.65	96.59	546.9

Area values are reported in km^2.

The temporal pattern is not linear. Water bodies increased slightly between 1990 and 2000 before falling sharply by 2010 and remaining low in 2020. Vegetation declined strongly in the first decade, recovered slightly by 2010, and then fell again by 2020. Floodplain area rose sharply by 2000, dipped slightly in 2010, and reached its highest recorded value in 2020. These sequences indicate instability in the ecological base rather than a smooth transition.

The photographic land-cover panels in Figure 4 make the planning implication visible. Water-body contraction, floodplain expansion, vegetation reduction, and built-up/bare land growth point to a landscape where floodwater movement and ecological storage are changing simultaneously.

It is easier to comprehend the meaning in terms of landscape adaptation. Nature-based adaptation cannot solely depend on keeping extra water in reserves. It must also consider the diminishing area of water-bodies, the removal of plants and vegetation, and built-up/bare land increases. This is the reason green infrastructures, restoration of ecosystems, agriculture sustainability, and vegetated erosion control becomes a primary aspect of the latter list.

4.4. Status of integration of eleven practices

Integrations of the eleven nature-based practices reveal an unevenness in the policy landscape. The highest integration value is found in natural flood retention and restoration with 0.615 followed by wetlands conservation with 0.603, and limited use of native species with 0.601. These integrations reflect the fact that some hydrological and ecological practices currently receive comparatively more attention.

The lowest value recorded is ecosystem restoration and protection with 0.378. On the other hand, green infrastructure development integration stands at 0.435, sustainable agricultural practices integration with 0.440, vegetation-based erosion control integration with 0.467, and sustainable urban planning with green space with 0.475. Such integrations are vital due to their relation to the land cover pressure mentioned above. There are less number of

Figure 4. Land-cover change.

plants, increase in built-up/ bare lands, and predominant livelihood sector of farming; but, the relevant practices still integrate poorly.

Table 4. Nature-based integration values.

Nature-based practice	Not	Slight	Neutral	Moderate	High	I_a
Green infrastructure development	34.3	11.1	20.2	15.2	19.2	0.435
Ecosystem restoration and protection	43.4	9.1	14.1	19.2	14.1	0.378
Natural flood retention and restoration	15.2	11.1	18.2	23.7	31.8	0.615
Sustainable urban planning with green space	28.8	17.7	11.1	19.7	22.7	0.475
Restoration and afforestation	23.2	19.2	9.1	26.3	22.2	0.513
Wetland conservation	19.7	6.1	15.2	31.3	27.7	0.603
Sustainable agricultural practices	32.8	12.7	16.6	21.7	16.2	0.440
Use natural barriers	24.2	15.7	10.1	27.8	22.2	0.520
Limited use of native species	14.6	18.6	8.1	28.8	29.8	0.601
Aquifer recharge and water-retention management	28.3	13.1	9.6	24.7	24.2	0.508
Erosion control through vegetation	30.8	17.7	7.1	22.7	21.7	0.467

Values before I_a are percentage shares by integration level.

The integration table shows that low values are not abstract weaknesses. Ecosystem restoration and protection

 doi: 10.70517/la20251152-03

has a not-integrated share of 43.4%, the largest in the table. Green infrastructure has 34.3% not integrated, and sustainable agricultural practices has 32.8% not integrated. The same categories later appear at the top of the priority ranking because their weak integration coincides with the flood, livelihood, and land-cover conditions already documented.

The intervention photographs in Figure 5 provide a compact visual inventory of the eleven practices. The panels are not used as evidence of implementation quality; they help readers distinguish the kinds of practices represented by the integration values.

Figure 5. Nature-based practices.

The image sequence reinforces a key empirical point: the intervention list spans riverbanks, farms, floodplains, urban drainage, wetlands, native vegetation, and settlement green space. Because these practices operate in different land-use settings, it would be misleading to treat them as one undifferentiated nature-based category. The integration index is useful precisely because it keeps them separate.

4.5. Priority ranking

The priority values identify where weak integration intersects with the high flood and livelihood exposure of the study area. Ecosystem restoration and protection ranks first with a priority value of 27.51. Green infrastructure development ranks second at 25.01, and sustainable agricultural practices ranks third at 24.80. The next group includes erosion control through vegetation at 23.58 and sustainable urban planning with green space at 23.25. These values show that the highest priority categories are not the categories with the strongest current integration.

A middle group includes aquifer recharge and water-retention management at 21.77, restoration and afforestation at 21.56, and use of natural barriers at 21.23. These practices remain important but do not carry the same combination of weak integration and immediate livelihood-land-cover relevance as the first group. The lowest priority values are limited use of native species at 17.66, wetland conservation at 17.57, and natural flood retention and restoration at 17.06. These lower values do not mean that wetlands and flood retention are unimportant. They indicate that their integration values are stronger and that the most urgent institutional repair lies elsewhere.

Table 5. Priority values.

Nature-based practice	I_a	Low integration	Priority value
Ecosystem restoration and protection	0.378	0.525	27.51
Green infrastructure development	0.435	0.454	25.01
Sustainable agricultural practices	0.440	0.455	24.80
Erosion control through vegetation	0.467	0.485	23.58
Sustainable urban planning with green space	0.475	0.465	23.25
Aquifer recharge and water-retention management	0.508	0.414	21.77
Restoration and afforestation	0.513	0.424	21.56
Use natural barriers	0.520	0.399	21.23
Limited use of native species	0.601	0.332	17.66
Wetland conservation	0.603	0.258	17.57
Natural flood retention and restoration	0.615	0.263	17.06

The priority values change the practical reading of the intervention list. The most visible hydrological measures should be protected, but the largest institutional deficit is located in restoration, green infrastructure, and livelihood-sensitive agriculture. Planning resources should therefore maintain stronger anchors while improving categories whose integration values remain low despite their relevance to the measured flood, livelihood, and land-cover conditions.

The ranked visual grouping in Figure 6 separates the highest, middle, and anchor categories. This presentation supports interpretation because it avoids implying that all practices must receive identical attention at the same time.

The practical interpretation of the ranking is not that low-ranked practices should be neglected. Wetlands and natural flood retention are central to hydrological protection, but they already have stronger integration values. The highest-ranked practices identify where added institutional effort is most needed, not where ecological value is exclusively located.

4.6. Moderate-integration gains

The moderate-integration shift focuses on the three weakest integration values. Ecosystem restoration and protection increases from 0.378 to 0.460 under the 25% shift and to 0.541 under the 50% shift. Green infrastructure development increases from 0.435 to 0.499 and then to 0.563. Sustainable agricultural practices increases from

Figure 6. Priority values.

0.440 to 0.501 and then to 0.563. The mean value for the three categories rises from 0.418 to 0.487 under the 25% shift and to 0.556 under the 50% shift.

Table 6. Integration strengthening.

Nature-based practice	Current value	25% shift	50% shift
Ecosystem restoration and protection	0.378	0.460	0.541
Green infrastructure development	0.435	0.499	0.563
Sustainable agricultural practices	0.440	0.501	0.563
Mean value	0.418	0.487	0.556

The strengthening calculation provides a measurable planning target. Moving half of the not-integrated responses for the weakest categories into moderate integration is sufficient to raise their mean above the 0.50 midpoint. This does not require universal adoption or full implementation. It requires concentrated institutional movement from non-integration to moderate integration in three categories closely connected to the observed flood, livelihood, and land-cover pressures.

The three photographic sequences in Figure 7 express the same calculation as a progression from current weakness toward stronger integration. The value of the figure lies in showing that the improvement is concentrated rather than dispersed across all eleven practices.

A stronger institutional position is available here as well. There is no need for planning effort at the beginning of an initiative to be spread evenly across all the nature-based activities. Restoration, green infrastructure, and sustainable agriculture can be promoted in land-use regulation, floodplain management, and local livelihood development.

Figure 7. Integration gain.

5. Discussion

5.1. Distinction between anchors and weak practices

The results reflect a clear distinction that is often ignored in nature-based flood planning. Priority values are not higher for practices with better integration. Natural flood retention and storage, wetland conservation, and limited application of native plants have relatively high integration values. However, their priority values are relatively lower, as the computation algorithm is designed to highlight the need for institutional strengthening, not ecological value alone. It is ecosystem restoration and protection, green infrastructure development, and sustainable agricultural practices that receive higher priorities because of low integration and high flood burden, land and water livelihoods, and land cover pressure.

From a policy-making perspective, there is a risk of placing too much emphasis on natural flood retention and wetlands preservation. While these measures are both popular and visibly hydrological in their role, the index calculation suggests retaining them but focusing on the other categories, as they require additional administrative effort and are connected to the process of land transformation, vegetation degradation, and flood exposure. Thus, priority ordering does not challenge ecological judgment. Instead, it frames it using evidence from the respondent and land-cover analysis.

5.2. Livelihood exposure and adaptation

The livelihood structure alters the way adaptation success is measured. The proportion of farming and fishing livelihoods (72.7%) implies that flood adaptation success cannot be gauged solely through protection of settlements or flood channel management. Instead, it should also be evaluated on the basis of the possibility to sustain livelihoods under the pressure of floods. The fact that 63.6% of respondents are farmers adds another aspect: these livelihoods might have limited tolerance for crop loss and seasonal relocation.

Sustainable agriculture ranks third since the integration computation treats it as a part of flood management. The process of flooding and adaptation includes floodplain farming, soil retention, crop pattern, and water retention. Therefore, the low integration value of sustainable agricultural practices points out the significant planning gap, implying that the dominant livelihood structure is not complemented by sufficient integration of agriculture into land use.

Another element that supports the priority ranking is fishing, as it highlights the necessity of preserving water bodies and wetlands functions in terms of livelihoods protection. Water-body loss reached 60.4% from 1990 to 2020. Given that fishing constitutes 23.7% of respondent livelihoods, it becomes obvious that this land-cover change is not merely a figure. Rather, it suggests that livelihoods dependent on fishing may experience pressure concerning livelihood security, food access, local mobility, and seasonal adaptation.

5.3. Ecological degradation and interventions needed

Land cover dynamics form the strongest ecological foundation for the ranking. There was an increase in built-up and bare land of 546.9%, vegetation cover reduction of 40.8%, and water bodies decline of 60.4%. These changes are indicative of a landscape where surface areas responsible for flooding have increased while the ability of the ecosystem to buffer and slow down floods was reduced. Floodplain area increase of 81.8% raises the importance of regulation in floodplains.

Ecosystem restoration and protection ranks first since it helps to recover the overall ecological system that protects the landscape from floods. Green infrastructure ranks second as it addresses an important challenge resulting from expansion of built-up and bare land areas. This landscape requires measures for managing surface water flow and creating conditions for its infiltration. Vegetated drainage, infiltration sites, roadside planting, retention sites, and permeable surfaces become essential. Erosion control by vegetation becomes important, given the decline in vegetative cover.

The results thus suggest several layers of interventions in planning: hydrological anchors, ecological restoration, green infrastructure, and agricultural practices. All of them come from the same calculation based on land cover dynamics and respondent profile.

5.4. Planning implications

Figure 8 synthesizes the key planning interpretations of the data. Between high flood burden, livelihood exposure to floods, and land cover pressure, there are two options: hydrological anchors and repair of the elements that support livelihoods.

Based on these findings, two nature-based flood adaptation practices need to be preserved: wetlands, flood retention and native species. On the other hand, five actions need to be reinforced: ecosystem restoration and protection, green infrastructure, sustainable agriculture, erosion control, and green-space urban planning.

In relation to the above, several planning suggestions can be provided: authorities responsible for land use must ensure that development regulations encompass restoration and green infrastructure; departments dealing with agriculture, in collaboration with planning units, have to give guidelines for farming in floodplain territories; wetlands and flood retention capacities must be preserved through zoning and enforcing; and finally, community participation must be encouraged during the implementation process because farmers and fishers are the most affected livelihood categories according to the respondent sample of 198 people.

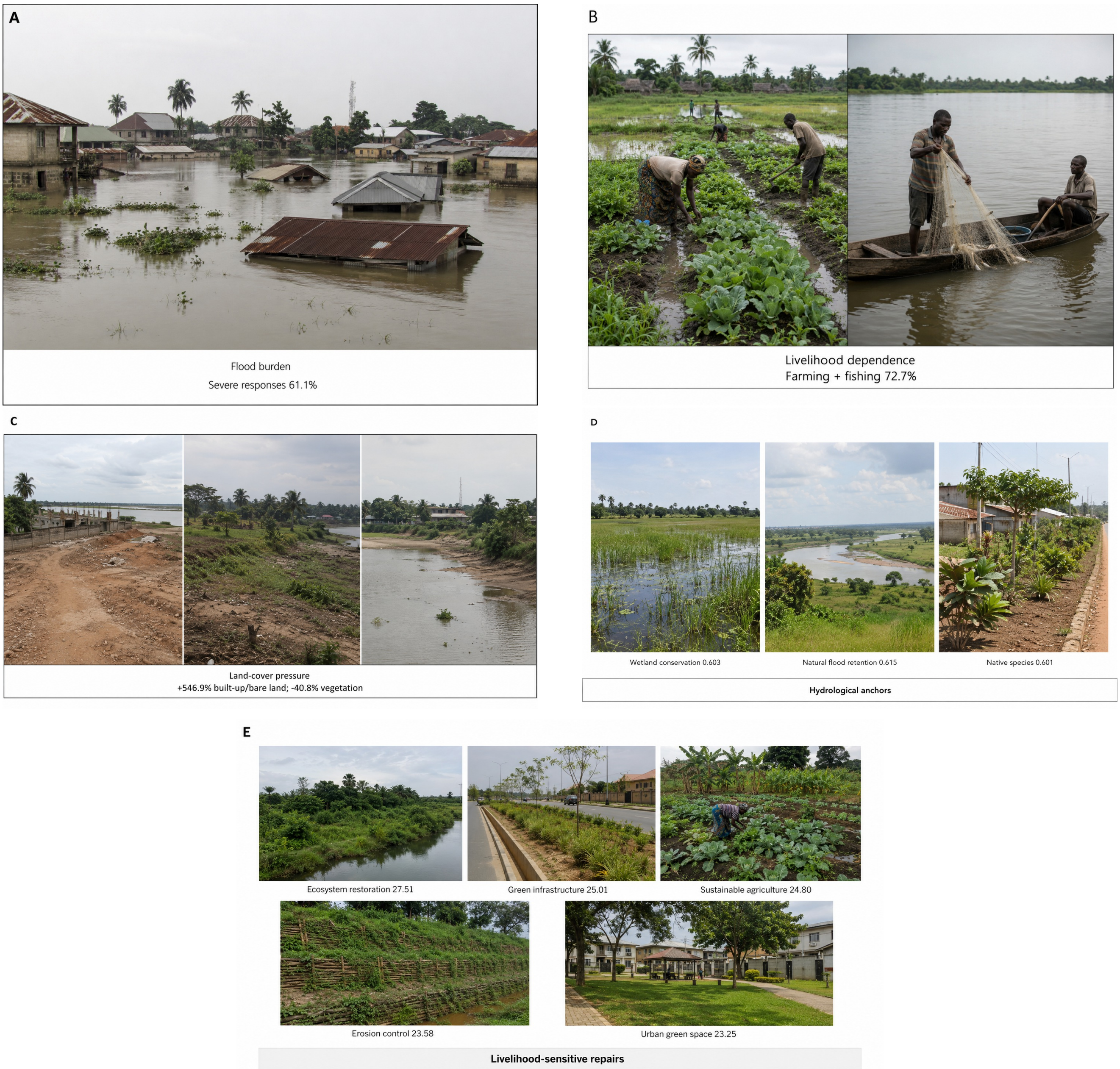

Figure 8. Planning synthesis.

5.5. Limitations

This calculation employs aggregate values. It cannot identify the occupations experiencing the biggest shock within each community, assess whether small farms are situated close to certain floodplains, or determine whether specific livelihoods assessed integration value differently. Therefore, the livelihood sensitivity indicator should be taken into consideration in the context of planning purposes, but not at the household level.

The class-level land cover values cannot establish exact locations where these transitions happened between 1990 and 2020. As a result, the future planning process must include household surveys, participatory mapping, high-resolution satellite images, simulations, cost assessment and other methods before making a decision.

The shift towards moderate integration indicator is a planning calculation and not a budget. It cannot forecast costs, maintenance, land acquisition, enforcement capabilities, community agreement and ecological performance in the case of new rainfalls. However, the value of the calculation lies in illustrating what categories need the most reinforcement efforts.

6. Conclusion

Overall, this analysis revealed what kind of nature-based flood adaptations require further improvement if the community flood shock, livelihood dependence, small/medium farm size and land cover transformation between 1990 and 2020 are considered in four communities: Odekpe, Umunakwo, Oko, and Okwe. In particular, ecosystem restoration and protection, green infrastructure and sustainable agriculture deserve top priority due to their low integration value and direct involvement into severe flood threat, livelihoods' dependence, land cover change and floodplain exposure.

The conclusion was reached based on the empirical values that reveal a significant flood shock in 121 out of 198 respondents or 61.1%; 72.7% livelihoods in the area consist of farming and fishing and 63.6% represent small and medium farms; there was an increase of 546.9% in built-up area, 81.8% in floodplain area, 40.8% decline in vegetation and 60.4% in water bodies. In other words, the issue involves more factors than mere hydrology.

Nevertheless, the priority list does not suggest any secondary role of wetlands, flood retention and native species in ecological terms since they are hydrological anchors of the area. The reason why these three adaptations were placed at the second position relates to the strong integration value and not the ecological importance.

Therefore, the priority list becomes double-sided: preservation of the anchors and rapid reinforcement of the not-integrated interventions. If 50 percent of the latter are shifted from the 'not integrated' level to moderate integration, then the average value jumps from 0.418 to 0.556.

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