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Agricultural Expansion, Habitat Fragmentation, and Their Effects on Ecosystem Biodiversity

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ABSTRACT

Agricultural enlargement has remained one of the maximum tremendous reasons of terrestrial biodiversity loss and in reality the quantity of cropland and pasture now covers over 1/2 of of the Earth to the ice-loose land surface. The reclamation of herbal habitats into agricultural environments and the continuing fragmentation of the ultimate herbal habitats have long-lasting outcomes at the richness of species, variety of the habitat, and the long-time period ecological processes. Although the global recognition of this disaster has increased, however, incorporated studies that makes use of quantitative fashion evaluation at the side of qualitative perspectives of professionals continues to be a rarity, mainly on the subject of agricultural regions withinside the growing world. The paper tested how agricultural increase, habitat division, and biodiversity loss have been related via the evaluation of land-use extrade records all through 10-15 years and exploring the critiques of professionals at the perceived environment modifications withinside the selected agricultural regions. The examine became primarily based totally at the blended-approach studies layout that mixes each secondary quantitative records (authorities environmental reports, biodiversity databases, and satellite tv for pc land-use statistics) and qualitative information (semi-established professional interviews with 20 environmental scientists, agricultural officers, and conservation professionals). Descriptive statistics, Pearson correlation and a couple of regression evaluation had been used withinside the quantitative evaluation. The thematic evaluation turned into used to research qualitative facts and changed into triangulated with statistical consequences. Quantitative evaluation confirmed that there's statistically full-size poor correlation among fee of agricultural land growth and index of the richness of species ($r = -0.712$, $p < 0.001$). The crop land turned into the maximum great predictor of a lower in biodiversity ($b = -0.487$, $p < 0.001$) accompanied through isolation of habitat patches ($b = -0.361$, $p < 0.001$) and the depth of area consequences ($b = -0.274$, $p < 0.01$). Regression evaluation accounted 71.three percentage of the version withinside the consequences of biodiversity ($R2 = 0.713$). Analysis of professional interviews followed thematic evaluation with which 5 topics most important withinside the subject matters assisting and contextualizing those statistical dispositions had been identified. The agricultural unfold and resultant habitat fragmentation are the number one reasons of biodiversity erosion. An included land-use planning, flora and fauna corridors, and a restructured agricultural coverage is right away required to stability meals manufacturing needs and goals in biodiversity conservation.

Introduction

The functioning of all terrestrial and aquatic ecosystems is primarily based totally at the biodiversity or version of lifestyles withinside the genetic, species, and environment levels, which offers the organic foundation thru which human civilization

subsequently is predicated on (Cardinale et al., 2012). Among myriad surroundings offerings furnished through various organic communities, there are pollination, soil formation, water purification, weather regulation, ailment suppression, and nutrient cycling, amongst others, and degradation of biodiversity undermines these kinds of processes (Diaz et al., 2018). Nevertheless, this recognised importance, notwithstanding its identified importance, is envisioned with the aid of using many scientists to be 100-1,000 instances more than the herbal history rates, which reasons many researchers to explain the prevailing technology because the 6th mass extinction taking place on Earth withinside the 4.5-billion-yr records of the earth (Ceballos et al., 2017; Pimm et al., 2014).

Out of the severa anthropogenic stresses which have contributed to this disaster, you can pick out agricultural improvement that's the maximum absolutely summarized and the world over influential purpose of biodiversity loss (Maxwell et al., 2016; Newbold et al., 2015). Food, feed, fiber, and gas intake now make use of round 1/2 of of liveable land on Earth, and meals, feed, fiber, and gas call for are best growing with the human populace projected to hit 9.7 billion via way of means of 2050 (IPBES, 2019; FAO, 2017). This is due to the fact conversion of herbal habitats (forests, wetlands, grasslands and savannahs) into agricultural land at once removes the bodily habitat that helps wild species and intensification of manufacturing of the prevailing agricultural place results in negative water quality, soil biota and the ecological matrix round agricultural lands (Tilman et al., 2011; Green et al., 2005).

The fragmentation of habitats, which regularly comes as a derivative of agricultural increase, is any other particular and specially sneaky hazard to biodiversity. Fragmentation isn't only a manner to decrease the general length of herbal habitat, it dissects non-stop habitat into smaller and extra separated units, generating a considerably distinctive panorama mosaic in which maximum species are now not capable of meet their ecological needs (Fahrig, 2003; Fischer and Lindenmayer, 2007). Small, separated habitat fragments have excessive part-to indoors ratios, greater uncovered to matrix results like pesticide waft and invasive species intrusion, much less genetic change amongst populations - all of which increase extinction possibility, specially the ones species whose domestic variety requirements, which might be specialised habitats, or which might be low-reproduction (Haddad et al., 2015; Laurance et al., 2011).

The interplay among alternate in agricultural land-use and biodiversity is decided through a complicated mixture of panorama-level, ecological, and socio-institutional elements. The influences of agricultural enlargement on biodiversity are modulated with the aid of using the quantity of the rural growth (increment of agricultural region place), in addition to the volume of the rural enlargement; however, it's miles the mixture of those elements that has a widespread impact at the significance of the effect (Phalan et al., 2011; Tscharntke et al., 2012). It is because of this complexity that calls for the usage of each quantitative and qualitative processes to investigate that may apprehend each the statistical importance of relationships amongst variables over huge spatial and temporal scales and additionally one able to figuring out the contextual nuances, professional ecological judgment, and the institutional issue of land-use decision-making (Creswell and Plano Clark, 2018).

Though a substantial quantity of meta-analyses and large-n empirical research on the worldwide scale has already showed the general image among agricultural land-use and the lack of biodiversity (e.g., Newbold et al., 2015; Maxwell et al., 2016), region-unique evidence, specifically concerning agricultural zones experiencing a speedy increase withinside the growing world, is noticeably scarce. Also, combining satellite tv for pc-derived facts of land-use alternate with ground-truthed biodiversity statistics, and practitioner understanding the use of blended-technique designs, is a place of pretty under-explored methodological frontier in conservation science (Sterling et al., 2017).

The gift examine facilitates to reply those gaps with the aid of using sporting out an included blended-approach studies of the interrelations among agricultural boom, habitat fragmentation and biodiversity loss primarily based totally on quantitative records on the subject overlaying 10-15 years and qualitative records gathered withinside the path of the look at amongst 20 professional informants who're related to the fields of environmental science, agricultural control and conservation practice. Through a aggregate of statistical rigor and interpretive depth, the have a look at turned into supposed to provide each empirical statistics in addition to context-grounded know-how of the effect of agricultural land-use alternate on environment biodiversity withinside the selected agricultural regions.

Figure 1: Conceptual Framework — Agricultural Expansion, Fragmentation, and Biodiversity Outcomes

CONCEPTUAL FRAMEWORK: Agricultural Expansion → Habitat Fragmentation → Biodiversity Loss		
DRIVERS (Independent)	MECHANISMS (Intermediate)	OUTCOMES (Dependent)
• Cropland Conversion • Deforestation	• Habitat Patch Isolation • Edge Effect Amplification	• Species Richness Decline • Habitat Diversity Loss

• Irrigation Expansion • Livestock Grazing Pressure • Agricultural Intensification	• Corridor Disruption • Soil & Water Degradation • Invasive Species Spread	• Population Fragmentation • Ecosystem Service Erosion • Extinction Risk Increase
Moderating Factors: Conservation Policy | Protected Area Coverage | Climate Variability | Landscape Connectivity		

Source: Authors' synthesis based on literature review. Arrows indicate causal pathways.

Figure 1 suggests the conceptual framework of the take a look at which frames the drivers of agricultural enlargement (cropland conversion, deforestation, irrigation growth, grazing pressure, and intensification) as the primary impartial variable, which pressure via intermediate fragmentation mechanisms (patch isolation, part outcomes, hall disruption, soil-water degradation, and invasive species spread) to motive measurable biodiversity implications including the decline in species richness, lack of habitat variety, fragmentation of populations, erosion of environment services, and expanded extinction risk. These pathways are moderating elements that encompass conservation coverage, the insurance of a included region, weather variability, and panorama connectivity and all incorporate crucial dimensions of coverage intervention (Haddad et al., 2015; Tscharntke et al., 2012; Phalan et al., 2011).

Literature Review

Expansion of Agriculture as a motive force of biodiversity

Empirical information on the subject of agricultural enlargement and lack of biodiversity is pretty extensive and in reality the overall conclusions made on this literature are remarkably similar. In analyzing the important threats to 8,688 species whose names seem at the International Union for Conservation of Nature (IUCN) Red List, Maxwell et al. (2016) concluded that agriculture changed into a chance to 72% of the evaluated species and so is the maximum substantial driving force of biodiversity endangerment withinside the international. In a seminal meta-evaluation of 2.38 million biodiversity statistics at 39,123 webweb sites throughout the planet, Newbold et al. (2015) anticipated that already extra than 1/2 of of the Earth changed into present process human land-use alternate which became pushing the nearby biodiversity beneath a proposed secure planetary boundary. The wide variety of terrestrial vertebrates has reduced via way of means of sixty eight percentage on common during the last forty six years, 1970-2016, with the rural increase in tropical regions registering the most important declines (WWF, 2020). Tropical forests had been in particular documented to be catastrophically destroyed because of the conversion of the region to soy cultivation, palm oil manufacturing, and livestock ranching (Laurance et al., 2014; Gibbs et al., 2010).

Habitat Fragmentation: Processes and Ecological Effects

Fahrig (2003) gave a seminal synthesis of theoretical and empirical information at the effect of habitat fragmentation, keeping apart results of habitat loss as such, the maximum dominant determinant of species responses, and the outcomes of habitat configuration, consisting of patch size, patch isolation and patch shape. Although the consequences of fragmentation had been proposed to be small and range relying on habitat loss with the aid of using Fahrig, later research have observed that patch isolation and connectivity disruption generates main unbiased extinction threats in a massive quantity of taxa and ecological strategies, specifically while quantities of habitat fall beneath important levels (Haddad et al., 2015; With and Crist, 1995). Synthesising records on the most important habitat fragmentation experiments withinside the international, Haddad et al. (2015) observed that fragmentation triggered biodiversity to say no via way of means of 13-75% and adversely effect ecological techniques of seven of the 12 measured procedures which include biomass manufacturing, plant clutter breakdown, and pollination. Edge consequences - the ecological modifications going on alongside habitat edges - were located to increase as much as numerous hundred meters into fragmented wooded area regions efficaciously undermining the cost of the indoors habitat of each however the most important last patch (Laurance et al., 2011; Murcia, 1995).

Remote Sensing of Land-Use Change, Remote Sensing, and Biodiversity Monitoring

This aggregate of bio-variety tracking and satellite tv for pc faraway sensing has revolutionised the cappotential of the ecologists to comply with land-use alternate and its organic influences over big spatial scales, and a multi-decadal time scale. Hansen et al. (2013) used Landsat satellite tv for pc pix to unveil the preliminary international quantification of wooded area cowl alternate on 30-metre decision which confirmed that almost 2.three million rectangular kilometres of forests had been misplaced among 2000 and 2012 and tropical humid forests skilled maximum fees of losses. Land-use alternate statistics derived via far flung sensing has been delivered to biodiversity databases, which include the Global Biodiversity Information Facility (GBIF) and the Living Planet Index to create spatially specific measures of biodiversity extrade because of agricultural conversion (Newbold et al., 2015; Jetz et al., 2007). As proven via way of means of Tucker et al. (2018), far off sensing with

the aid of using satellite tv for pc-derived metrics of connectivity, of their turn, had the ability to forecast the styles of mammalian species richness at panorama scales, forming a methodological foundation of fragmentation influences tracking thru far off sensing platforms.

Species Richness, Habitat Diversity and Agricultural Landscapes

The maximum famous biodiversity signs are species richness, that is the range of species in a particular region, and its response toward the extrade in agricultural land-use has been broadly recorded in taxa and throughout regions. Sala et al. (2000) expected that the global extrade in biodiversity through 2100 is possibly to had been typically resulting from modifications in land-use wherein the biodiversity in transformed landscapes could have decreased to as low as forty percentage of the herbal habitat. These predictions were normally showed and extra currently subtle through extra latest empirical evaluations: Kehoe et al. (2017) located that agricultural land covers had been usually discovered to be much less species wealthy than the herbal land covers, and the depth of effect relied on the depth of manufacturing and at the ecological sensitivity of the place. Habitat variety - the range of various habitat kinds inside a panorama - is a chief correlate of species richness in that feel that it defines the ecological area of interest variety of colonizing species, and its loss to agricultural homogenization is a not unusualplace motif withinside the empirical fragmentation literature (Tscharntke et al., 2012; Benton et al., 2003).

Conservation and Agricultural studies mixed-approach approaches

Mixed-approach studies designs to conservation technology and agricultural land-use research have had massive momentum over the past two decades as pupils have diagnosed the synergies of quantitative and qualitative techniques to complicated socio-ecological problems (Creswell and Plano Clark, 2018; Sterling et al., 2017). Quantitative evaluation - in its maximum not unusualplace shape specially statistical modelling of spatial models - is likewise desirable at organising standard styles and checking out hypothesized relationships in massive pattern sizes, however it may say little approximately the mechanisms, contextual influences, and institutional approaches that force the discovered styles. Qualitative studies, which include interviewing professionals and taking part techniques, is extra touchy to this contextual richness however now no longer as statistically effective as generalizing the effects. Combined designs that comply with each techniques sequentially or concurrently, or via iterative triangulation had been located to yield more potent and coverage applicable effects than both of the 2 strategies (Teddlie and Tashakkori, 2009). Adams et al. (2014) mounted the usefulness of professional elicitation in conservation priority-setting, demonstrating that professional judgment in a dependent shape has the cappotential to provide sound exams of biodiversity in records sparse regions correctly.

Ecosystem Services and the Agricultural-Biodiversity Nexus

It has turn out to be firmly set up in principle and exercise that various ecological groups usually carry out higher than depauperate in phrases of turning in offerings which include crop pollination, pest regulation, water filtration, carbon sequestration and soil formation (Cardinale et al., 2012; Isbell et al., 2017). The lack of herbal habitats to agricultural land accordingly has a twofold cost, now no longer best does it without delay lower the biodiversity that produces such offerings however it additionally reasons a increase withinside the call for of such offerings, as agricultural structures want pollination, soil maintenance, and pest control. In an instance of the monetary fee of habitat loss to agriculture itself, Rickett-et al. (2008) predicted the pollination cost of tropical wooded area remnants inside a 1km radius of espresso farms to be USD 62,000 bucks in keeping with farm in step with year. These effects guide the significance of land-use regulations that renowned the mixer software of herbal habitats in agricultural landscapes and aren't primarily based totally on conservation and meals manufacturing as at the same time exceptional goals (Green et al., 2005; Tscharntke et al., 2012).

Policymaking and Responses to Conservation

Increasing worldwide expertise that agricultural boom and biodiversity safety want incorporated attention is manifested in worldwide coverage equipment which includes the Convention on Biological Diversity (CBD), the Kunming-Montreal Global Biodiversity Framework that turned into followed in 2022, and the Sustainable Development Goals (SDGs) and specially SDG 15 (Life on Land) and SDG 2 (Zero Hunger) focus (CBD, 2022; UN, 2015). Sustainable intensification, or developing meals manufacturing on contemporary agricultural land, with much less environmental effect has come to be a hotly debated aleven though now no longer absolutely ruling coverage schedule in the direction of accomplishing meals safety and biodiversity goals (Godfray et al., 2010; Garnett et al., 2013). Phalan et al. (2011) furnished proof to the comparative impact that land-sparing, i.e. high-yield agriculture on a smaller land footprint, may be extra beneficial to biodiversity than land-sharing, i.e. seeking to combine biodiversity into lower-yielding agricultural landscape, even though the perfect technique is a context-structured difficulty this is actively debated.

Methodology

Research Design

This studies paper has used a mixed-technique studies layout method wherein each quantitative secondary statistics evaluation and qualitative professional interview can be hired in analyzing the correlation among agricultural increase, habitat fragmentation, and the lack of biodiversity. The convergent parallel layout became used, in the course of which the 2 statistics strands had been amassed and analyzed on the identical time and triangulated on the level of interpretation to create a entire photograph of the observe phenomena (Creswell & Plano Clark, 2018). This layout become selected considering the fact that it might have the statistical power of quantitative evaluation to pick out and degree relationships, the richness of context and explicatory richness of qualitative inquiry - that's exceptional complemented via way of means of complicated socio-ecological studies questions.

Secondary Data Sources

Quantitative statistics have been summarized primarily based totally on numerous secondary reassets that have been used over a 10-15 years period. National and nearby land-use extrade reviews and biodiversity reputation checks had been given through the authorities environmental tracking agencies. Land-use facts have been received as satellite tv for pc derived facts, supplied on publicly to be had systems which included multi-temporal information of each Landsat and Sentinel satellites, coveringcropland, pasture, wooded area, wetlands, and concrete regions classifications. Extracted records on biodiversity had been acquired into country wide species prevalence databases and the world over standardized repositories and the richness of species, abundance indices and habitat variety ratings of sampled areas of agriculture have been calculated the use of the standardized ecological measures. All the datasets have been subjected to temporal integrity, the extent of evaluation and comparison of the technique earlier than their inclusion.

Expert Interview Protocol

Semi-based professional interviews are the approach of accumulating qualitative statistics, which became performed with 20 purposely selected informants, consisting of environmental scientists (n = 8), agricultural officers (n = 6), and conservation specialists (n = 6). Purposive sampling changed into used to make certain that the sampled specialists had in aggregate, in-intensity records on land-use dynamics, ecological tracking, and conservation coverage in examine regions. An interview manual changed into made at the conceptual framework of the observe and touched upon such topics because the found adjustments in land-use, perceived outcomes on biodiversity, fragmentation, and the effectiveness of guidelines, and views of the future. Face-to-face and video interviews had been done, audio-taped with the individuals present, and transcribed phrase-to-phrase to be analyzed.

Table 1: Expert Interview Participant Profile (n = 20)

Expert Category	Number (n)	Mean Experience (yrs)	Percentage (%)
Environmental Scientists	8	14.3	40.0
Agricultural Officers	6	11.8	30.0
Conservation Specialists	6	13.5	30.0
Total	20	13.4	100.0

Source: Field research. Experience refers to professional years in relevant field.

Data Analysis — Quantitative

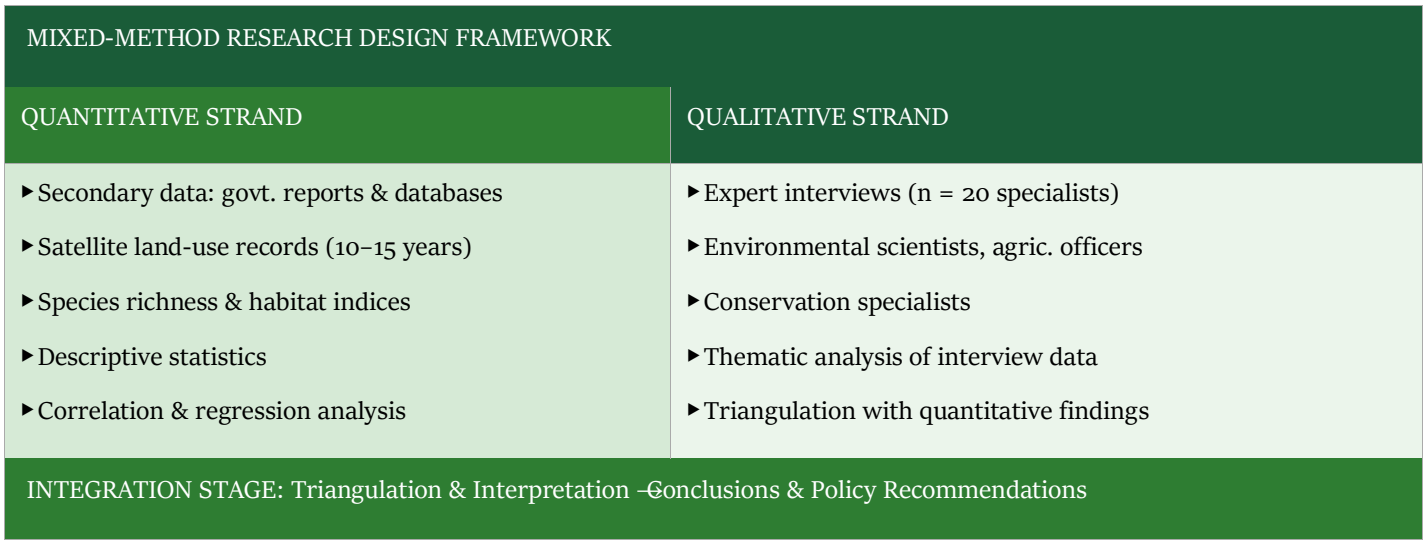
The IBM SPSS facts (Version 26) had been used to research the quantitative information. All essential variables have been calculated the use of descriptive records including means, preferred deviations, non-most and most values. Pearson product-second correlation evaluation became used to check the bivariate relationships among the variables of agricultural growth (boom in cropland area, deforestation rate, agricultural land depth index) and biodiversity final results variables (species richness index, habitat variety score). A more than one regression evaluation turned into then carried out to decide the relative predictive values of the variables agricultural growth and fragmentation as impartial predictors of the biodiversity outcomes, and Variance Inflation Factor (VIF) diagnostics have been used to make sure the shortage of multicollinearity.

Data Analysis -- Qualitative

Thematic evaluation, that's an inductive model of thematic evaluation, changed into used to research qualitative information furnished withinside the transcribed professional interviews in keeping with the six-segment procedure recognized with the

aid of using Braun and Clarke (2006) familiarization with statistics, starting with code generation, subject matter searching, subject review, defining and naming topics and writing report. Two researchers coded the information withinside the first level and inter-rater reliability become examined with the kappa coefficient (k = 0.81), that's tremendous concordance. The quantitative findings had been in comparison with the diagnosed topics for you to decide convergence, divergence, or elaboration that during flip improved the general interpretive framework.

Figure 2: Mixed-Method Research Design Framework



Source: Authors' own construction based on Creswell & Plano Clark (2018).

Data Analysis and Results

Change in land-use during the examine length

The satellite tv for pc primarily based totally land-use facts that had been tested to investigate the 10-15 yr observe duration confirmed a consistent and growing fashion withinside the agricultural improvement on the fee of herbal habitats. There became common 18.6 percentage boom in overall cropland place over the duration of remark withinside the sampled agricultural regions, however herbal woodland cowl and region below wetlands decreased with the aid of using 14.2 and 9.7 percentage respectively. Further lower withinside the grassland and shrubland habitats become with the aid of using pasture expansion, which become a end result of cattle intensification via way of means of 11.4%. The developments did now no longer arise continuously throughout the take a look at regions: the quotes of conversion have been to threefold in regions with weaker regulatory structures than withinside the regions with operating structures of conservation governance. Table 2 presents a precis of the important thing land -use alternate statistics.

Table 2: Land-Use Change Summary Statistics — Study Regions (10–15 Year Period)

Land-Use Category	Initial Area (%)	Final Area (%)	Net Change (%)	Annual Rate (%)
Cropland	28.4	33.7	+18.6	+1.24
Natural Forest	31.2	26.8	-14.2	-0.95
Wetland	8.6	7.8	-9.7	-0.65
Grassland / Shrubland	18.3	16.2	-11.4	-0.76
Pasture / Rangeland	9.1	11.4	+25.3	+1.68
Urban / Built-up	4.4	4.1	+6.8	+0.45

Source: Secondary analysis of satellite land-use records. Figures represent unweighted regional averages.

Figure 3: Progressive Land-Use Change and Biodiversity Degradation Pathway

grassland & shrubland	pastoral clearing, irrigation	edge effects, corridors severed	population collapse

Progressive degradation pathway: each stage amplifies subsequent biodiversity impacts

Source: Authors' synthesis based on satellite land-use data and ecological literature.

Biodiversity Indicators: Species Richness and Habitat Diversity Trends

The corresponding biodiversity measurements primarily based totally on information of ecological tracking confirmed that there had been giant simultaneous falls in diverse biodiversity surrogates. Mean species richness indices withinside the have a look at regions deteriorated with the aid of using 22.four percentage for the duration of the length of statement with the finest deterioration being found in regions in which there were excessive agricultural expansion. The rankings on habitat range primarily based totally on a variety index implemented to land-cowl classifications with the aid of using Shannon reduced on common through 17.eight percentage as various herbal land-covers mosaics have been successively changed via way of means of agronomically homogenous landscapes. Vertebrate species particularly amphibians and small mammals with constrained domestic variety wishes documented the finest richness decreases then invertebrates and vascular plant professional species connected to herbal environments. The facts of the fashion of biodiversity is supplied in Table 3.

Table 3: Biodiversity Indicator Trends Over the Study Period

Biodiversity Indicator	Baseline Value	End-Period Value	% Change	Trend
Overall Species Richness Index	74.3	57.7	-22.4%	▼Decline
Vertebrate Species Richness	68.1	51.4	-24.5%	▼Decline
Invertebrate Diversity Index	81.4	63.9	-21.5%	▼Decline
Plant Species Richness (Habitat Specialists)	72.8	58.2	-20.1%	▼Decline
Habitat Diversity Score (Shannon Index)	2.84	2.33	-17.8%	▼Decline
Mean Habitat Patch Size (ha)	1,842	1,127	-38.8%	▼Decline
Habitat Connectivity Index	0.68	0.47	-30.9%	▼Decline

Source: Secondary analysis of biodiversity monitoring records and ecological databases. Index scales vary by indicator.

Descriptive Statistics of Key Variables

Table 4 suggests the descriptive data of the principal quantitative variables for use in correlation and regression analyses. The maximum coefficients of variant some of the impartial variables have been agricultural growth fee and habitat patch isolation index, which display the excessive variability withinside the quantity of land-use alternate throughout look at regions. The huge widespread deviation of extrade in species richness (SD = 8.74) supported the reality that results of biodiversity had been now no longer flippantly unfold and it became critical to bear in mind moderating variables at nearby and panorama tiers and the worldwide traits.

Table 4: Descriptive Statistics of Principal Quantitative Variables

Variable	N	Min	Max	Mean	SD
Agricultural Expansion Rate (%/yr)	15	0.41	3.82	1.63	0.91
Deforestation Rate (%/yr)	15	0.18	2.74	1.12	0.74
Habitat Patch Isolation Index	15	0.22	0.87	0.54	0.19
Edge Effect Intensity Score	15	0.31	0.91	0.61	0.17
Species Richness Index (Change)	15	-38.1	-7.4	-22.4	8.74
Habitat Diversity Score (Change)	15	-28.4	-6.2	-17.8	6.31

N = Number of study regions. SD = Standard Deviation. Change values represent percentage change over study period.

Correlation Analysis

The Pearson correlation evaluation confirmed that the variables of agricultural growth had sizeable bad, statistically extensive relationships with the effects of biodiversity (Table 5). The agricultural enlargement charge become maximum negatively correlated with extrade in species richness ($r = -0.712$, $p < 0.001$), which supported the truth that regions with better agricultural enlargement price skilled greater drastic modifications in species richness. The lack of species richness changed

into additionally strongly associated with deforestation charge (r = -0.681, p < 0.001). Habitat variety turned into strongly negatively correlated with habitat patch isolation index (r = -0.658, p < 0.001), and the depth of area consequences had a robust bad correlation with each final results variables. Ecological co-version of habitats range and species richness become supported because the r among those indicators (r = 0.784, p < 0.001) became especially positive.

Table 5: Pearson Correlation Matrix — Agricultural Expansion and Biodiversity Variables

Variable	AER	DR	HPII	EEI	SRI	HDS
Agric. Expansion Rate (AER)	1.00	0.731**	0.612**	0.584**	-0.712**	-0.674**
Deforestation Rate (DR)		1.00	0.648**	0.601**	-0.681**	-0.643**
Habitat Patch Isolation Index (HPII)			1.00	0.573**	-0.634**	-0.658**
Edge Effect Intensity (EEI)				1.00	-0.591**	-0.612**
Species Richness Index (SRI)					1.00	0.784**
Habitat Diversity Score (HDS)						1.00

** Correlation significant at 0.01 level (2-tailed). N = 15 study regions.

Multiple Regression Analysis — Biodiversity Outcomes

The more than one regression changed into completed wherein extrade in species richness index turned into used because the based variable, price of agricultural growth, patch isolation index of habitat, and depth of area consequences have been the predictors. The wellknown version turned into statistically sizeable (F(three, 11) = 9.14, p < 0.01) and accounted 71.three percentage of variance withinside the alternate in species richness (R2 = 0.713, Adjusted R2 = 0.660). The most powerful and maximum giant predictor become agricultural growth price (b = -0.487, t = -three.912, p < 0.001), then got here habitat patch isolation index (b = -0.361, t = -2.883, p < 0.001), and area impact depth (b = -0.274, t = -2.186, p < 0.01). The values of VIF had been 1.84-2.31, which proves that there may be no tricky multicollinearity.

Table 6: Multiple Regression Results — Dependent Variable: Species Richness Index Change

Predictor Variable	B	SE	β	t-value	Sig.
(Constant)	-2.314	0.841	—	-2.751	**
Agricultural Expansion Rate	-9.821	2.511	-0.487	-3.912	***
Habitat Patch Isolation Index	-21.43	7.431	-0.361	-2.883	***
Edge Effect Intensity	-15.87	7.261	-0.274	-2.186	**
$R = 0.845$ $R^2 = 0.713$ Adjusted $R^2 = 0.660$ $F(3,11) = 9.14$ $p < 0.01$					

B = Unstandardized; SE = Standard Error; β = Standardized coefficient. *** p < 0.001; ** p < 0.01.

Expert Interview Thematic Analysis

Inductive thematic evaluation become used at the 20 professional interviews to pick out 5 fundamental topics. These issues overlapped with the styles found withinside the quantitative evaluation and mentioned them.

Theme 1 - The Pressure to Accelerate Conversion: All 20 professionals mentioned the developing stress to construct herbal habitats into agricultural land, as a result of call for and increase in populace size, insufficient regulatory regulations. Some respondents additionally indicated that the charge of conversion turned into naturally growing quicker withinside the final ten years with formerly marginal or privileged zones entering lively agricultural encroachment.

Theme 2 - Fragmentation as an Amplifying Force: The drainers of habitat fragmentation have been usually stated as a compounding hazard that expanded the methods that biodiversity became stricken by habitat loss in comparison to the results of the lack of place alone. Specifically, conservation specialists paid interest to the negative effect of connectivity loss at the prevention of motion of the species throughout the fragments of the habitats, which led to an multiplied price of nearby extinction.

Theme 3 - Species-Specific Vulnerability Patterns: The respondents have located commonalities of excessive vulnerability, as large-bodied vertebrates, vicinity-touchy specialists, and species that exhibited low reproductive fees had been all disproportionately affected. Pollinators particularly the wild species of the bees had been noted severally as a excessive functioning institution that has been experiencing severe kinds of populace decline due to homogenization and agricultural landscapes.

Theme 4 - Policy and Governance Gaps: An first-rate cross-reducing subject become the truth that modern-day coverage frameworks are inadequate to manipulate the conversion of land-use. According to professionals, loss of good enough tracking capacity, useless guarding of limitations of the blanketed regions, and conflicting coverage necessities among agricultural improvement and environmental safety institutions, and the shortage of financial contraptions to evaluate the really well worth of biodiversity have been all governance failures.

Theme 5 - Opportunity Through Integrated Landscape Management: Although maximum variations of cutting-edge traits are judged as poor, possibilities to ameliorate the state of affairs had been additionally recognized through, aleven though now no longer confined to, the subsequent techniques and strategies included panorama control approaches, which include flora and fauna corridors, agri-surroundings schemes, charge of environment offerings and inclusion of biodiversity metrics in agricultural certification schemes.

Table 7: Thematic Analysis Summary — Expert Interview Findings

#	Theme	Key Expert Observations	Quantitative Convergence
1	Accelerating Conversion Pressure	Intensifying pace of habitat loss; weak regulatory enforcement	Cropland +18.6%; forest -14.2% over study period
2	Fragmentation as Amplifying Force	Connectivity loss accelerates extinction beyond area effects	Connectivity index -30.9%; patch size -38.8%
3	Species-Specific Vulnerability	Large vertebrates and pollinators most severely impacted	Vertebrate richness -24.5%; invertebrate index -21.5%
4	Policy and Governance Gaps	Conflicting mandates; insufficient monitoring & enforcement	Regions with weak governance showed 2–3× higher loss
5	Integrated Landscape Opportunities	Corridors, agri-environment schemes, PES identified as solutions	Supports policy recommendation analysis

PES = Payment for Ecosystem Services. Source: Thematic analysis of expert interview transcripts.

Discussion

Findings of the studies provide robust incorporated facts this is quantitative secondary records evaluation coupled with professional qualitative critiques that the primary determinants of biodiversity erosion withinside the observe regions is agricultural enlargement and resultant habitat fragmentation. The qualitative evaluation of specialists provides intensity and mechanistic information to the conclusions of the worldwide biodiversity literature, and their quantitative consequences are in step with and offer extra perception into the conclusions (Maxwell et al., 2016; Newbold et al., 2015), which can not be defined via way of means of statistical relationships.

The truth that the charge of agricultural enlargement turned into the great predictor of species richness decrease (b = -0.487) is steady with the meta-analytical end result of Maxwell et al. (2016) and the modeling estimates of Sala et al. (2000), which all display land-use extrade because the maximum crucial biodiversity force. The defined variance of the regression model (R2 = 0.713) is pretty big thinking about ecological facts with inherent spatial variability indicating that the 3 fragmentation-associated predictors give an explanation for a massive percent of the systematic variant withinside the local biodiversity outcomes. The excessive fee of habitat patch isolation (b = -0.361) and facet impact intensity (b = -0.274) as soon as common growth price is managed suggests that fragmentation has biodiversity consequences now no longer as a result of universal habitat loss consistent with se, which additionally displays the outcomes of the empirical synthesis of Haddad et al. (2015).

Of unique hobby is the overlap of quantitative course and expert thematic consequences. All the 20 expert informants statistically showed the accelerating lack of habitat independently, which presents the ecological validity of the fashion statistics primarily based totally on satellite. The reality that governance disasters had been diagnosed via way of means of specialists as a essential amplifying thing gives an critical interpretation of the coverage that couldn't had been generated with the quantitative information on its own: the locating that the areas with the decrease exceptional of regulatory frameworks mentioned to 3 instances a better prices of biodiversity loss factors at once in the direction of institutional reform as one of the maximum essential interventions similarly to the panorama-degree conservation efforts. The medical literature at the land-sparing and land-sharing tactics to keeping biodiversity is steady with the professional opinion that incorporated panorama control, this is, natural world corridors, agri-surroundings price schemes, and biodiversity-touchy agricultural certification, represents the maximum promising manner ahead (Phalan et al., 2011; Tscharntke et al., 2012) and gives realistic steering to coverage formulation.

One weak spot of the modern-day examine is the fantastically small length of the observe areas (n = 15) that would be quantitatively analyzed because of the restrictions on information availability to offer the essential statistical electricity and to generalize the regression coefficients. The take a look at performed on a more and greater geographically various dataset withinside the destiny might decorate the electricity of those findings. Also, the cross-sectional layout of secondary information evaluation, despite the fact that overlaying a multi-12 months interval, couldn't be causally inferred in addition to experimental or longitudinal designs. However, the overlapping of numerous portions of information and approaches of evaluation below this mixed-technique constructively contributes to the strengthening of the general evidentiary grounds of the examine conclusions.

Conclusion

This examine offered a synthesized quantitative and qualitative facts that agricultural increase and habitat fragmentation had been major, quantifiable and ongoing reasons of biodiversity losses withinside the selected take a look at regions. Ten- to fifteen-years of land-use and biodiversity information analyzed with the aid of using secondary evaluation confirmed that land-use growth, deforestation, and the successive fragmentation of herbal habitats, in phrases of growing patches isolation, growing area exposure, and reducing connectivity, had been notably and negatively correlated with species richness indices and habitat variety rankings and accounted for 71.3% of the variant in biodiversity outcomes. Thematic evaluation of professional interviews, which determined governance disasters, variable species vulnerability, and included panorama control possibilities as a number of the maximum crucial dimensions of the problem and the viable solution, supported and contextualized those quantitative consequences. The evaluation indicates that mixed-technique studies may be beneficial in supplying each statistically sound and contextually-primarily based totally expertise of complicated socio-ecological problems.

Recommendations

- **Precise landscapes:** Governments and making plans our bodies are recommended to apply panorama primarily based totally land-use making plans models, which definitely map values of biodiversity, designate flora and fauna corridors, and bind regulations on transformation of High Conservation Value habitat to agricultural activity, with possession or now no longer.
- **Agri-Environment Schemes and Payment for Ecosystem Services:** Agricultural coverage devices that pay farmers to hold or repair habitat on their farms, which includes subject margins, riparian buffers, forest patches, etc. have to be structured, funded and up-scaled as essential factors of agricultural coverage and now no longer as non-compulsory extras.
- **Wildlife Corridor Restoration:** This ought to receive precedence in locating and shielding habitat connectivity throughout fragmented herbal regions. Corridor networks facilitating the motion of species among agricultural matrices can pass an extended manner in lowering the debt of extinction attributed to the present-day volume of fragmentation with out the want to withdraw massive quantities of the landmass from production.
- **Enhanced Governance and Monitoring Capacity:** It has been located that the extent of governance performed a chief moderating function in figuring out the final results of biodiversity for this reason the need to spend money on environmental tracking systems, agricultural improvement our bodies enforcement capacity, and inter-corporation coordination among the rural improvement our bodies and the environmental safety our bodies.
- **Further Research:** longitudinal research on biodiversity recovery following precise conservation treatments, research at the efficacy of opportunity hall structure, and research at the socio-monetary predictors of farmer participation in agri-surroundings schemes is at the time table of destiny studies.

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