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Smallholder farmers shift crops in the face of global change.

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Biological Sciences - Article

Keywords: Agrobiodiversity, climate change, food system, farmers choice.

Posted Date: October 5th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10561199/v1

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Additional Declarations: There is **NO** Competing Interest.

Abstract

Smallholder farmers' ability to adapt to socio-environmental changes strongly relies on crop diversity and composition. Yet, how crop portfolios change over time and affect nutrition and climate adaptability remains poorly understood. We address this gap by combining 1,748 surveys of smallholder farmers across 15 globally distributed sites with climate suitability projections and nutritional profiles of 158 crop species. Farmers reported 6,234 crop abandonment and adoption events over the past half-century, highlighting highly dynamic crop portfolios. Although changes varied across sites, five showed a consistent shift from cereals (e.g., maize, sorghum) towards vegetables and fruits. Climate change was the dominant driver of abandonment (25%), particularly for drought-sensitive staples, while markets and value chains primarily shaped adoption (22%). Changes in crop portfolios revealed a trade-off between nutritional diversity and future climate suitability: vegetable adoption may improve dietary quality but increase climate vulnerability through higher water requirements. These findings highlight the need to reconcile immediate nutritional and economic needs with long-term climate adaptation.

Main

The growing reliance on a small number of dominant food crops have drawn increasing international attention since the 1990s (1) and raise concerns about the ability of food systems to buffer shocks and combat malnutrition (2). While countries have diversified their crop portfolios since the 1960s, crop commodities across countries have become increasingly similar owing to the global spread of oilseeds, sugar crops, and cereals, particularly wheat and rice. This trend has led to the homogenization of landraces and, therefore, a loss of crop genetic diversity, often accompanied by unsustainable agricultural practices (3). Although growing data availability has improved our understanding of global crop supply trends, how these trends translate into farmers' crop choices remains poorly understood.

Bridging this gap is essential for anticipating risks to local food security and sustainability, particularly in regions dominated by smallholder farming, where farmers are on the frontline of climate change and crop portfolios are changing most rapidly (3, 5). Because these communities rely heavily on locally produced food, shifts in crop choices have immediate consequences for livelihoods, nutrition and resilience that extend beyond the short-term economic outcomes emphasized in previous work (6). Recent review of empirical studies reported shifts from staple cereals to high-value horticultural crops supplying urban markets (7, 8), highlighting potential implications for raising concerns about rural nutrition, climate vulnerability (9, 10), and increasing competition for water resources (11). However, most analyses stop at formulating hypotheses; rarely do they quantify the potential trade-offs associated with changes in which crops are grown. Assessing these trade-offs requires integrating information on crop climatic suitability and nutritional value together across diverse crop species, yet most studies remain restricted to major staple crops and. Although broader analyses exist (12), nutritional dimensions are rarely incorporated.

Farmers' decision-making process is complex (13) and involves interactions among socioeconomic, institutional, market, cultural, and environmental drivers (13–16). While climate change is known to affect agricultural production (17), its relative importance compared to other determinants in driving farmers' crop choices remains debated (18, 19).

Here, we (i) quantify local crop adoption and abandonment events, (ii) identify the drivers reported by farmers, and (iii) evaluate the climatic and nutritional consequences of these changes. Our approach moves beyond analyses constrained by heterogeneous local studies and aggregated agricultural statistics by using standardized interviews with 1,748 farmers across 15 smallholder farming communities (Fig. 1). This provides the first harmonized, farm-level comparison of crop choice dynamics and their drivers across regions (20, 23, 24). By combining these data with a crop-specific Climatic Suitability Index and a Nutrient Density Index spanning 19 macro- and micronutrients for the 158 crop species, we reveal how ongoing changes in the composition of farmers' crop portfolios are simultaneously reshaping climate adaptation and nutritional outcomes.

Results

Smallholders' crop composition is highly dynamic over time. Across the 15 sites, farmers reported 2,916 crop abandonment and 3,348 crop adoption events over the last 50 years (1970–2020) (SI Appendix, Fig. S1). In total, 158 crop species were reported to have changed through time. Identity of crops vary substantially with marked variation among crop groups, across sites, and among farmers within sites. Within most sites, only two or three crop species accounted for more than 40% of reports (SI Appendix, Fig. S4).

From these 158 crop species, only 10 were mentioned as abandoned or adopted by more than 10% of all interviewed farmers across sites (Fig. 2A). These included both major crops (e.g., maize, rice and wheat) and minor crops (e.g., sweet potato and finger millet). Cereals represented the largest share of reported changes (35% of all events). Adoption mainly involved maize and rice, whereas abandonment primarily concerned wheat and locally-important cereals such as millet and sorghum. Roots and tubers followed a similar pattern, whereas fruits and vegetables were predominantly adopted (Fig. 2A).

Sites sharing similar topo-climatic conditions exhibited comparable crop trajectories (Fig. 2B). High-altitude temperate sites were characterized by widespread abandonment of cereals and pulses, lowland equatorial sites by heterogeneous abandonment of diverse crop species, including sugarcane and tropical tubers, and arid sites by consistent sorghum abandonment. Crop adoption followed a similar clustering, with tropical sites mainly adopting fruits and vegetables, temperate sites maize, and arid sites rice.

Crop changes are mainly driven by climate change and market. Crop changes were primarily driven by climate change (25% of reports) and changes in markets and value chains (22%), followed by shifts in food habits (16%). Crop functional groups responded differently to these drivers, considered separately or in combination (Pearson's residuals, Fig. 3; SI Appendix, Fig. S6).

Changes in markets and value chains were most frequently associated with crop adoption (29% of adoption events) and, when linked to abandonment (12%), farmers reported the loss of profitability. Changes in food habits mainly promoted the adoption of staple crops such as potatoes, maize, rice, cassava and sweet potato to strengthen households' food security. Other drivers—including access to agricultural inputs, societal changes (e.g., agricultural policies and rural outmigration), and non-climatic biophysical changes (e.g., soil fertility and pests)—were reported less frequently (Fig. 3). Overall, farmers cited multiple drivers in 44% of crop change events (SI Appendix, Fig. S5). A Dagomba farmer from Ghana illustrates the interaction between climatic and cultural drivers: "*The rainfall patterns have changed, and it makes it harder to grow some of our traditional crops [...] we are forced to grow what people need based on their taste.*"

Reports of cereal adoption were mainly associated with climate change but also motivated by the value of coproducts such as fodder. Vegetable adoption was primarily driven by market opportunities and improved access to agricultural inputs. However, these interacting drivers also generated trade-offs. As a Bassari farmer from Senegal explained after adopting vegetables despite their high water demand: "*Vegetables help us get some money, but you need to water them. If you don't go to the well very early in the morning, you won't find water and need to go further.*"

Climate and nutritional trajectories in crop portfolios were not always aligned. For each study site, we calculated the median Crop Suitability Index (estimated under the SSP5–8.5 climate scenario for 2041–2070 using GCM) and Nutrient Density Index (based on estimated average daily requirements for 19 macro- and micronutrients) for adopted and abandoned crops, respectively, independently of crops that are maintained. We then calculated the ratio between adopted and abandoned crops to assess how changes in crop portfolios can affect the balance between climate adaptation and nutritional outcomes. In three sites (East region of Sri Lanka, Kumbungu in Ghana, and Ba in Fiji; n = 462 farmers), adopted crops were better suited to future climatic conditions but had lower nutritional value than the crops they abandoned (Fig. 4). These trade-offs mainly reflected the replacement of nutrient-rich fruits and vegetables by cereals better adapted to projected climatic conditions. For example, in Kumbungu (Ghana), farmers abandoned several nutrient-rich vegetables, including tomato and okra, while adopting Asian rice, which showed high future climatic suitability locally (SI Appendix, Table S2). The opposite pattern was observed in four sites (Lonquimay in Chile, Chiredzi in Zimbabwe, Amambay in Paraguay, and Puna in Argentina), where adopted crops had higher or similar nutritional value but lower climatic suitability than abandoned crops. Four additional sites (Juruá River in Brazil, Vavatenina in Madagascar, Bassari country in Senegal, and Tsimane' territory in Bolivia) showed little change in either climatic suitability or nutritional quality, whereas only one site (Western Highlands in Guatemala) exhibited simultaneous improvements in both dimensions. These patterns were robust across alternative climate scenarios and global circulation models (SI Appendix, Fig. S7).

Discussion

This provides the first harmonized, farm-level comparison of crop choice dynamics and their drivers across diverse socioecological contexts. We show that crop portfolios are highly dynamic, combining widespread shifts shared across topoclimatic zones with substantial heterogeneity in farmers' decisions. We further demonstrate that these changes are primarily driven by interacting climatic and market forces, with important consequences for both climate adaptation and nutritional outcomes.

Crop changes. Our findings complement previous analyses of global food supply (3) by showing that the expansion of maize, rice, and horticultural crops is also occurring in smallholder farming systems. At the same time, crop adoptions and abandonments vary widely among farmers, and among sites reflecting differences in farmers' knowledge, values, needs, past experiences (13, 26–28). This heterogeneity likely contributes, both to maintaining agrobiodiversity within sites (29–31), and the adaptation of small farms when this diversity of species supports complementary biological and cultural functions (32, 33). But common trends across sites, i.e., replacement of local cereals by globally distributed crops shown here (i.e., maize and rice), support current concerns about the erosion of crop genetic diversity, biocultural heritage, and the resilience of global farming systems (34,35).

Methodologically, our study demonstrates the value of standardized farmers' reports for documenting long-term crop dynamics. National agricultural statistics and supply datasets provide invaluable broad-scale information but generally lack the spatial (national or administrative) and biological (species or commodity groups) resolution needed to detect local crop adoption and abandonment of specific species and varieties (3, 37–41). Furthermore, these data present some bias. For instance, we identified discrepancies between our results and Khoury's analysis of crop supply data (4). For cassava and peas, our results indicate increased cultivation, whereas Khoury's studies report a decline in supply. This discrepancy may reflect the self-consumption of part of the production on small farms, which is not captured in national supply statistics. This is consistent with previous studies showing that agricultural statistics often poorly represent contexts dominated by small-scale farming and informal crop supply (36).

Extending standardized monitoring to complete crop portfolios and intraspecific diversity would substantially improve our understanding of agrobiodiversity change. This highly dynamic nature of crop portfolios also reflects farmers' continuous adaptation to the multiple changes they face and their ability to respond rapidly to them.

Drivers of crop change. Climate variability and market conditions together explained nearly half of reported crop changes, highlighting that farmers' decisions emerge from the interaction of environmental and socioeconomic constraints rather than from single drivers. Although studies conducted in industrialized agricultural systems have questioned the importance of climate as a driver of crop choices (18), our results suggest that climate plays a central role in smallholder farming, where livelihoods remain tightly coupled to local environmental conditions (20). These findings are consistent with evidence that adaptation frequently occurs through crop substitution and adjustments in cropping systems (42–44).

The interaction between climate and markets also helps explain the growing cultivation of commercially valuable crops observed across several study sites, confirming previous local studies (10, 21, 25). While such strategies may improve household incomes, they may simultaneously increase dependence on irrigation, external inputs, or market fluctuations, thereby generating new vulnerabilities and potential social-ecological traps (45, 46). Beyond climate and markets, our findings confirm that crop trajectories are also shaped by changing food preferences, agricultural policies, labor availability, rural outmigration, and environmental degradation, cultural identity and values, illustrating the multidimensional nature of crop change (47-49, 13). These results further emphasize the importance of combining large comparative analyses with locally grounded qualitative research to better understand how farmers' decision-making are grounded into socio-cultural contexts (22).

Trade-offs between climate adaptation and nutrition. Our analyses reveal that the interplay between adoptions and abandonments within crop portfolios may generate trade-offs between climate adaptation and nutritional quality. In three sites, the replacement of nutrient-rich fruits and vegetables by cereals increased climatic suitability under future conditions while reducing the nutritional quality of crop portfolios. Conversely, other sites showed the opposite trajectory, with nutritional gains accompanied by lower climatic suitability of the species. However, our study does not account for species that are maintained or for potential changes in crop area, which prevents us from assuming that the trajectories we describe fully reflect the capacity of entire on-farm crop portfolios to provide nutrients or remain suitable under future climate projections. Rather, our results indicate a probable trend.

These contrasting trajectories highlight that promoting horticultural crops may simultaneously improve dietary diversity while increasing dependence on water resources and other agricultural inputs (7), potentially reducing the resilience of local farming systems under future climatic conditions (50). More broadly, they raise the question of whether increased production of market-oriented fruits and vegetables necessarily translates into improved local nutrition. Commercialization may redirect production away from household consumption, reducing food sovereignty and increasing dependence on external markets (51, 52). Although our study does not quantify these consequences directly, it demonstrates the importance of jointly considering climatic adaptation and nutritional outcomes when evaluating agricultural transitions.

While the expansion of major crops follows well-documented global trends, farmers' crop trajectories remain highly heterogeneous, reflecting locally specific interactions among climatic, socioeconomic, and cultural drivers. In addition, shifts in crop portfolios frequently generate context-dependent trade-offs, illustrating how short-term adaptation strategies may increase longer-term vulnerabilities. At the same time, the diversity of farmers' responses highlights the adaptive capacity of smallholder farming systems and the ongoing reconfiguration of agrobiodiversity. Future agricultural policies and crop promotion strategies should jointly consider climatic suitability, nutritional quality, socioeconomic constraints, and farmers' knowledge and priorities. Integrating these dimensions will be essential to support agricultural transitions that strengthen both the resilience and the nutritional sustainability of local food systems under climate change.

Materials and Methods

Data collection. We conducted 1,748 in-person surveys across 15 globally distributed field sites with place-based communities engaged in nature-dependent livelihoods (Fig. 1). All data were collected within the framework of the Local Indicators of Climate Change Impacts (LICCI) project, which aims to document Indigenous Peoples' and local communities' perceptions of climate change impacts and integrate this knowledge into scientific and policy discourse (20). Data collection and coding adhered to LICCI's standardized protocol designed to ensure both local relevance and cross-cultural comparability (24). A dedicated subsection of the protocol focused on agricultural systems, including trends in crop composition and diversity. Data were collected by co-authors with longstanding relationships in the study communities. Free Prior and Informed Consent (FPIC) was obtained from all participants, either orally or in writing, and all participants retained the right to withdraw at any time. Ethical approval was obtained from the Ethics Committee of the Autonomous University of Barcelona (CEEAH 4781) and, where necessary, from relevant national and local authorities (e.g., customary leaders, cultural heads, chiefs). Study sites were selected to capture variation across climate zones, ecoregions, and livelihood systems, while maintaining environmental and socio-cultural homogeneity within sites (24), while for this study we only included sites where agriculture was the main livelihood strategy. Within each site, surveys were conducted in 1–5 villages. Only villages with 20–500 households were included; larger villages were subdivided for sampling efficiency. Households were randomly selected using local census data. Within households, one or two members, typically household heads, were interviewed using a quota-based convenience approach to ensure balance by age and gender and address potential biases. The final sample included 840 women (48%) and 900 men (52%), ranging in age from 14 to 95 (median ± SD = 48 ± 15.4 years).

Trajectories of crops composition change. To understand local crop composition dynamics and their underlying drivers, we conducted household-level surveys focused on changes in crop species composition. Respondents were asked to identify three crop species they had adopted or increased in area and three they had abandoned or decreased, since they began farming independently (we estimated the age starting between 15 and 20 years olds, see *SI Appendix*, Fig. S1). After standardizing species names and resolving taxonomic inconsistencies using POWO (2025), we categorized the reported species into ten functional groups: cereals, fruits, pulses, nuts, oilseeds, roots and tubers, vegetables, herbs and spices, starchy fruits, and others. We tested whether the distribution of functional groups differed significantly between adopted and abandoned crops using a Chi-squared test. The analysis was conducted across all 10 functional groups; however, for clarity in Figs. 2 and 3, *nuts*, *herbs and spices*, and *starchy fruits* were merged into the *Others* category. To evaluate within-site variation in crop diversity trajectories, we calculated a within site level agreement score, defined as the proportion of respondents reporting the same directional change (adoption or abandonment) for a given species. To assess across-site variation, we constructed a Bray–Curtis dissimilarity matrix using species presence weighted by their site-level agreement scores, and conducted Principal Coordinates Analysis (PCoA) using the R package vegan (53). The axes of our PCoA explain 44.68% (axes 1 & 2) of the variance for crop abandonments and 41.77% (axes 1 and 2) for crop adoption. To compare the distributions of site-level

agreement across sites, we calculated pairwise Wasserstein distances between sites, which quantify the dissimilarity between two probability distributions. We then used Wilcoxon tests to assess differences in the mean pairwise Wasserstein distances. Distances were computed using the wass_test function from the *twosamples* R package (54).

Drivers of change. During interviews, respondents were asked to explain their motivations for adopting or abandoning each crop species. We categorized their responses into seven broad drivers: *(1) climate change* (e.g., drought), *(2)* changes in market and/or value chain (e.g., price inflation), *(3)* societal changes (e.g., policy shifts), *(4)* changes in biophysical conditions unrelated to climate (e.g., soil fertility loss), *(5)* shifts in food habits (e.g., new dietary preferences), *(6)* changes in input availability or access (e.g., seed market access, loss of heirloom seeds), and *(7)* other factors (e.g., labor shortages). We evaluated the contribution of these drivers to both adoption and abandonment events within functional crop groups using Chi-squared tests. To further contextualize the influence of each driver, we incorporated qualitative background information provided by the co-authors who collected data. These co-authors, deeply embedded in the study sites, offered insights into local societal, environmental, cultural, economic, and political dynamics shaping crop management decisions. We selected illustrative case studies to exemplify the role of each driver in agrobiodiversity change, supported by direct quotations from respondents (see SI Appendix, Table 1). Additionally, data collectors provided information on each crop's intended use (i.e., self-consumption or market-oriented at local, regional, national, or international levels). Finally, to understand how climate change perceptions shape crop decisions, we used a complementary dataset documenting farmer-reported climate impacts on crops. This information was gathered during the same fieldwork period, through semi-structured interviews and focus group discussions within the same communities (see also (22)).

Crop Suitability Index. To assess future climate suitability for each crop species at each site, we developed a *Crop Suitability Index*. This index was based on the modelled relationship between species occurrence data obtained globally from the GBIF and Genesys databases, and nine bioclimatic, topographic and edaphic variables for the 1971–2010 period (see *SI Appendix Methods*). Three modelling algorithms (Generalised Additive models, Random Forest and Maximum Entropy) were used to model this relationship. For each algorithm, we ran three repeats, each with three sets of cross-validation, giving us a total of 27 models per species and performance was assessed using cross-validation (three random 20% data-splits) and the True-skill statistics (TSS). The final ensemble model was obtained from the weighted average across all models. Suitability was then projected under future climate conditions according to the SSP3–7.0 and SSP5–8.5 emissions scenario for the 2041-2070 and 2071–2100 period and the three Global Circulation Model (GCM) : UKESM1-0-LL from the UK Met Office, GFDL-ESM4 from the Geophysical Fluid Dynamics Laboratory and the MPI-ESM1-2-HR from the Max Planck Institute for Meteorology. The index shown in the results (Fig. 4) represents the mean of values computed from three GCMs under the SSP5–8.5 scenario (2041–2070), reflecting a high-emission, worst-case pathway. We choose this scenario to avoid underestimating potential local risks. Recent past and future climate data were retrieved from CHELSA (55) at a 10 arc-min resolution (~20km at the equator). Topographic and edaphic variables were kept constant under future scenarios. Future climate

suitability is thus represented as the probability of each crop species to occur at each site under the future climate scenarios considered ranging from 0 to 1, where 1 indicates higher probability. More details about the modeling procedure are provided in the *SI Appendix Methods*.

Nutrient Density Index. To evaluate the potential nutritional implications of crop abandonment and adoption, we calculated a *Nutrient Density Index* (NDI) for each reported crop species using a modified version of the SAIN (Score of Nutritional Adequacy of Individual Foods) index (56). This Index (NDI) represents the mean percentage of the Estimated Average Requirement (EAR) for one person daily (young woman) for 19 nutrients, normalized by the food's energy density (kcal/100g). Nutrients considered include protein, fiber, vitamin A (RAE), thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, vitamins C, D, and E, calcium, potassium, iron, magnesium, zinc, copper, and selenium. Nutrient reference values were based on Allen et al. (57), with fiber set at 25 g/day as per EFSA (2010). Nutrient data were extracted from the USDA FoodData Central database (58). Nutrient scores were calculated for 82 species, representing 52% of all species reported.

Implications. To assess the relative adaptability of species to climate change, we first computed the *Crop Suitability Index* ranging from 0 to 1, where higher values indicate greater suitability of crops under future climate scenarios. The index was calculated separately for species that were adopted and those that were abandoned, independently of crops that are maintained. Similarly, we computed a *Nutrient Density Index* (ranging from 0 to 1) to evaluate the nutritional contribution of each species. For each site, we calculated the ratio of medians (adopted/abandoned) for both indices. Then, we compared the mean values of adopted and abandoned species (weighted by their respective site-level agreement) for the indices using a Wilcoxon t-test. Comparing the climate and nutrition ratios allowed us to explore potential trade-offs between adaptive resilience and nutritional quality in species turnover. Two sites were removed from the final analysis; Mafia Island due to the lack of climatic data to run the *Crop Suitability Index* and Inner Mongolia because farmers reported only crops adoption event, which does not allow us to build the ratio of medians (adopted/abandoned) for both indices.

Declarations

Author Contributions: V.P., V.L., D.R., A.P-F., and V.R-G. design research; V.P., V.L., D.R., E.O.V., S.P., F.L., and A.T., performed research; V.P., and F.L.,analyzed data; A.P-F., R.C., R.C, Z.C., F.C., E.C., E.K.G., M.G., A.I., A.J., M.L., E.M.N.A.N.A., J.M., P.S., and R.W. collected data; V.P., V.L., and D.R wrote the paper.

Acknowledgments and funding sources

We thank the editorial board members and the anonymous reviewers for their helpful comments; and Hoel Queffelec for his invaluable assistance and insightful guidance on applying the Wasserstein distance. We thank all the farmers who voluntarily participate in our study. Research leading to this paper received funding from the European Research Council under an ERC Consolidator Grant (FP7-771056-LICCI). This work contributes to ICTA-UAB "María de Maeztu" Programme for Units of Excellence of the Spanish Ministry of Science, Innovation and Universities (CEX2024-001506-M funded by

MICIU/AEI/10.13039/501100011033). SP and FL are supported by the Calleva Foundation. SP and AT received seed funding for the Harvest for Health Breakthrough Crop Challenge from the Foundation for Food and Agriculture Research (FFAR).

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Figures

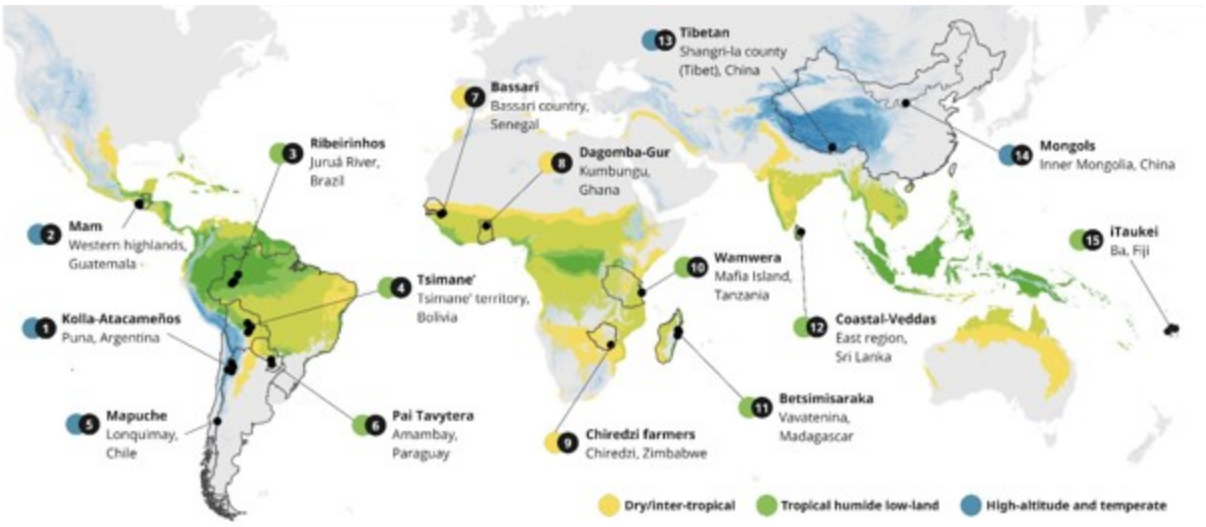

Figure 1

Indigenous and local communities participating in the study across topo-climatic zones. In the following order: communities, site and country. **(1)** Kolla-Atacameños, Puna, Argentina, **(2)** Mam (Mayan), Western highlands, Guatemala, **(3)** Ribeirinhos, Juruá River, Brazil, **(4)**Tsimane', Tsimane' territory, Bolivia, **(5)** Mapuche, Lonquimay, Chile, **(6)**Pai Tavytera, Amambay, Paraguay, **(7)** Bassari, Bassari country, Senegal, **(8)** Dagomba, Kumbungu, Ghana, **(9)** Chiredzi' farmers (Ndau, Shangaan/Tsonga), Chiredzi, Zimbabwe, **(10)** Wambwera (Bantu), Mafia Island, Tanzania, **(11)**Betsimisaraka, Vavatenina, Madagascar, **(12)** Coastal-Veddas, East region, Sri Lanka, **(13)** Tibetan, Shangri-la country (Tibet), China, **(14)** Mongols, Inner Mongolia, China,**(15)** iTaukei, Ba, Fiji. Our study covers three broad topo-climatic regions; Dry / inter-tropical regions (yellow), tropical humid low-land (green) and high-altitude and temperate climate regions (blue).

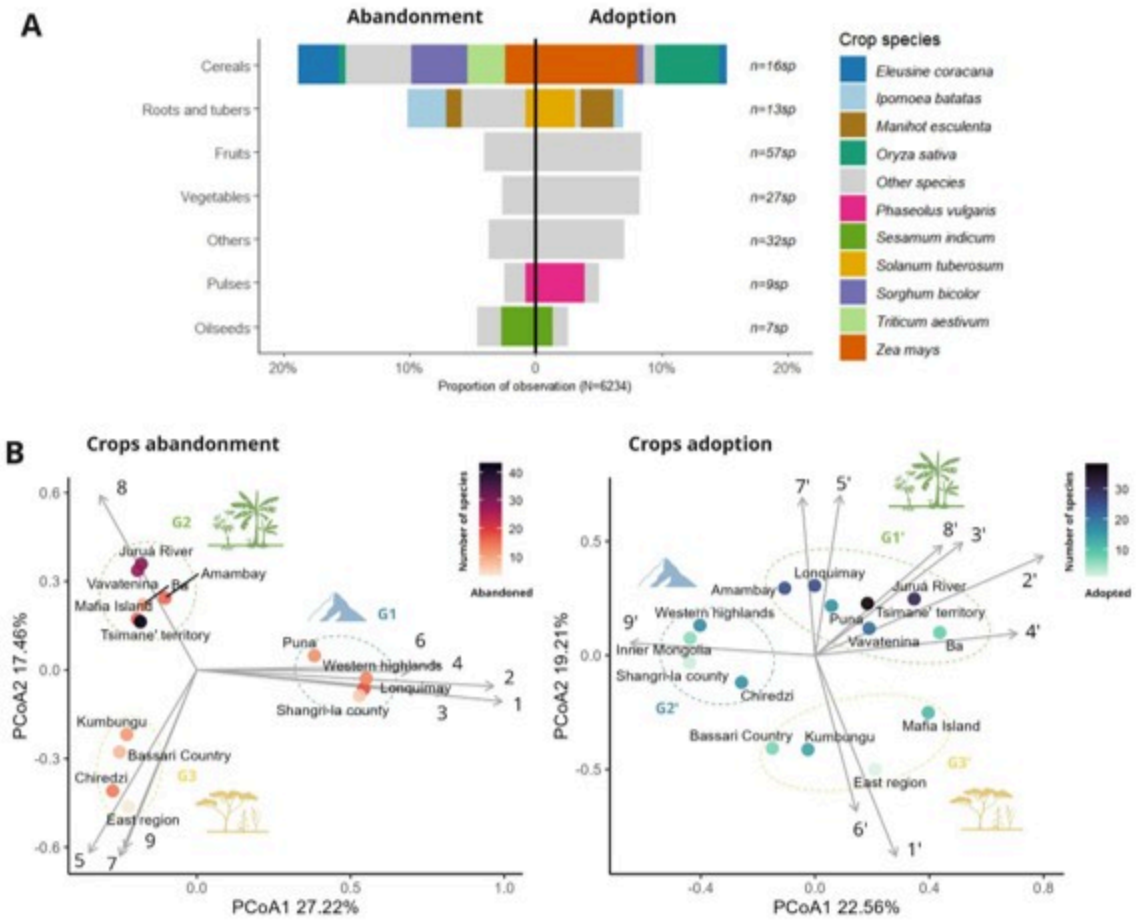

Figure 2

(A) Proportion of observations by functional groups and main species abandoned (left) and adopted (right) and *n* indicates the number of species reported by functional groups. The main species- cited by over 10% of all informants, are displayed in colors and the remaining species are grouped as “other species”. *(B)* Site dissimilarity based on crop species number and composition of abandoned and adopted. PCoA biplot of crop abandonment and adoption based on species composition dissimilarity matrix using Bray-Curtis index weighted with crops’ site-level consensus. Arrows indicate the direction and magnitude of correlations for the nine crop species contributing most to the ordination axes (scaling = 0.5). Black numbers (1–9) denote species ranked from the strongest to the weakest contributors on each plot: for the abandonment (1) wheat, (2) faba bean, (3) oat, (4) barley, (5) bambara groundnut, (6) quinoa, (7) sorghum, (8) sugarcane and (9) finger millet; for the adoptions (1’) rice, (2’) banana, (3’) avocado, (4’) cassava, (5’) chili, (6’) cashew, (7’) tomato, (8’) watermelon and (9’) maize. Colored icons and ellipses indicate topo-climatic regions where communities dwell and cultivate: Dry / inter-tropical regions (yellow), tropical humid low-land (green) and high-altitude and temperate climate regions (blue).

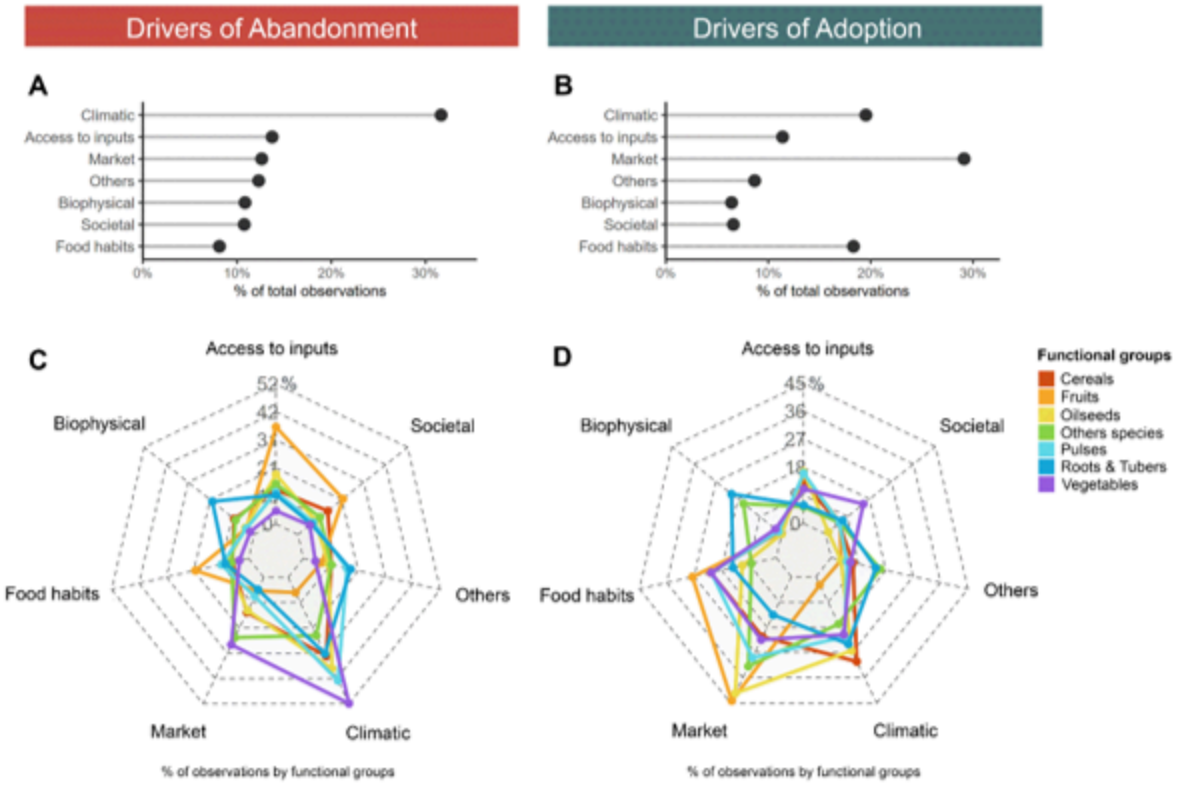

Figure 3

Proportion of observations of crops changes events by functional groups explained by drivers reported by farmers. *(A)*Proportion of observations of crop abandonment by driver, calculated relative to the total number of crop abandonment observations (n = 2,916). *(B)*Proportion of observations of crop adoption by driver, calculated relative to the total number of crop adoption observations (n = 3,348). *(C)* and*(D)* Proportion of crop abandonment and adoption observations by functional group for each driver, calculated relative to the total number of abandonment or adoption observations within each functional group. Results of the analysis of Pearson's residuals from a chi-square test performed on drivers of abandonment (*X-squared* = 810.87, df = 54, p-value < 2.2e-16***) and adoption (*X-squared* = 1410.2, df = 54, p-value < 2.2e-16***) of functional groups (see *SI Appendix Fig.S6*).

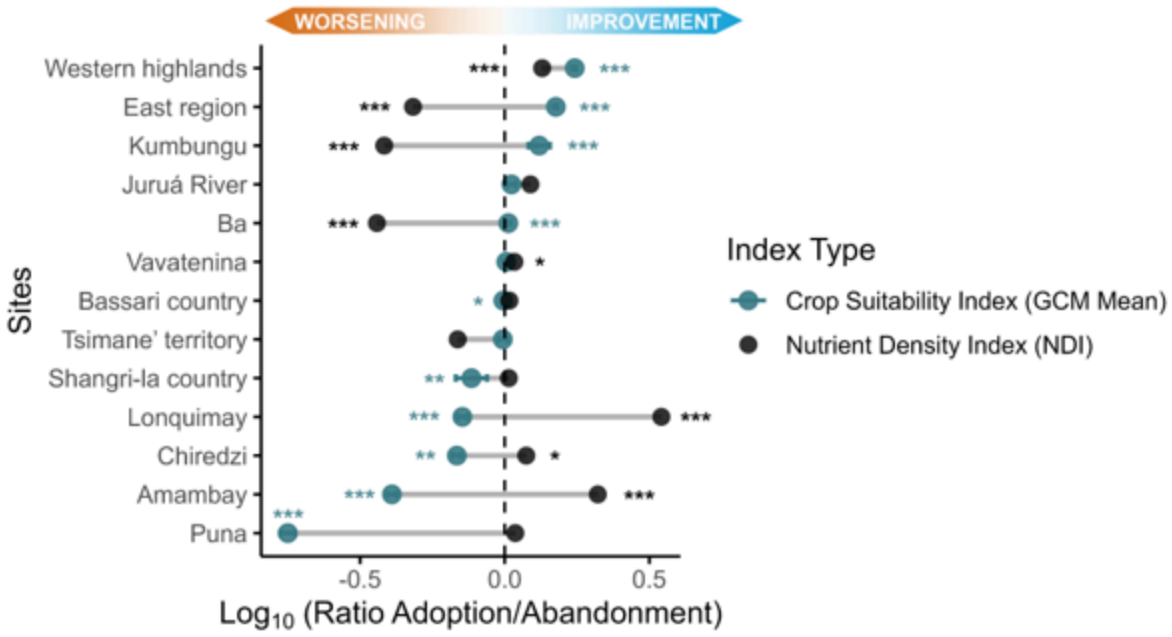

Figure 4

Trend and trade-off in crop composition shift suitability to climate change and nutritional quality per study site. Blue dots represent the ratio of median Crop Suitability Index values for adopted crops relative to those for abandoned ones, under the SSP5–8.5 scenario (2041–2070), averaged across three global climate models (GCMs error bars). Black dots represent the ratio of median Nutrient Density Index values for adopted crops relative to those for abandoned ones (calculated for 19 nutrients). Ratios values are expressed as the logarithm of the ratio between adoption and abandonment. Positive values indicate higher index values among adopted crops relative to abandoned ones (toward a crop composition more suitable to climatic scenarios or of a higher nutritional quality), while negative values indicate the opposite. Differences between the median values of adopted and abandoned species (within sites) for each index (blue: Crop Suitability; black: NDI) were tested using a Wilcoxon rank-sum test weighted with site-level agreement. Significance levels are indicated as follows: (***) $P < 0.001$; (**)$P < 0.01$; (*) $P < 0.05$; (.) $P < 0.1$; (ns) non-significant.

Supplementary Files

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