Wild foods contribute to higher dietary diversity in India

Jennifer Cheek (Jennifer.ZavaletaCheek@sdstate.edu)
South Dakota State University
Nathalie Lambrecht
Charité – Universitätsmedizin Berlin, corporate member of Freie Universität Berlin and Humboldt-Universität zu Berlin, Institute of Public Health,
Bowy den Braber
University of Copenhagen, Department of Geosciences and Natural Resource , Management,
Laura Rasmussen
University of Copenhagen
Nirali Akanchha
Indian School of Business
Dhanapal Govindarajulu
Indian School of Business
Andrew Jones
University of Michigan
Ashwini Chhatre
Indian School of Business

Article

Keywords:

Posted Date: September 16th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-2053935/v1

Version of Record: A version of this preprint was published at Nature Food on June 22nd, 2023. See the published version at https://doi.org/10.1038/s43016-023-00766-1.

Abstract

Wild foods, from forests and common lands, can contribute to food and nutrition security. Previous studies have established correlations between forests and dietary diversity. We use matching, a rigorous, quasi-experimental method, and monthly-interval data to assess the contribution of wild foods to women's diets. We collected 24-hour recall data from 570 households monthly from November 2016 to November 2017 in two districts in East India. We found that wild foods contributed positively to diets, especially in June and July when consumption of wild foods was highest. Women who consumed wild foods had higher average dietary diversity scores (12 and 15% higher in June and July, respectively) and were more likely to consume nutrient-dense, dark green leafy vegetables, than women who did not eat wild foods. Our results show that access to wild foods is critical to addressing undernutrition in rural India.

Main

Globally around three billion people do not have access to healthy diets (I. FAO, UNICEF, WFP and WHO, 2021). Inadequate consumption of sufficiently diverse and nutritious food sources leads to micronutrient deficiencies and an increased risk of morbidity and mortality (Black et al., 2008). Among women, undernutrition is associated with poor maternal health and childbirth outcomes, reduced work capacity, and adverse intergenerational consequences such as stunting and poor cognitive development in children (Victora et al., 2021) India, where this study was conducted, has the highest population of undernourished people globally (200 million in 2015–2017) and almost half of young children are stunted (FAO, 2018). India shares a quarter of the global hunger burden, so understanding dietary diversity dynamics in India has the potential to improve global averages (Von Grebmer, 2017). As climate change threatens to make the poorest even more vulnerable to food insecurity (IPCC, 2019), understanding how people can improve the quality of their diets is of paramount importance.

Many of the world's poorest people depend on natural resource collection for subsistence (Miller et al., 2020; Newton et al., 2016) and an estimated 1.5 billion people (just under 20 percent of the global population) live within 5 km of a forest (Newton et al., 2020). In India, around 88 million people live within 5 km of a forest. Additionally, India has over 71 million hectares of forests (or about 22 percent of its geographical area) ((FSI), 2019). Taken together, the highest population of undernourished people globally and the size and dependence of forests justifies our focus on India.

A growing evidence base suggests that forests and common lands contribute to the dietary quality of people living in close proximity to forests (High Level Panel of Experts (HLPE), 2017; Rowland et al., 2017). Forests have even been described as 'the supermarket of the wild' (Wunder et al., 2014). Wild foods can supply many essential micronutrients and contribute to caloric intake, especially during the lean season (Avik Ray, 2022; Wunder et al., 2014) or at times of low agricultural production (Vinceti et al., 2013).

Not only do forests have the potential to impact diets directly through the consumption of food, they can also impact diets indirectly through increased income from forest products or through regulating services such as pollination which can increase agricultural yields (Gergel et al. 2020). Most of the research to date has found positive associations between forest-level variables like the proportion of forest cover (Galway et al., 2018; Ickowitz et al., 2014),distance to forests (Rasolofoson et al., 2018) or spatial configuration of forests (Rasmussen et al., 2020) and people's dietary diversity. (Ickowitz et al., 2014) used Demographic Health Survey Data from 21 African countries and found that children up to five years old who lived in areas with more trees had more diverse and nutritional diets. Similarly, Galway et al. (2018) showed that deforestation was associated with lower dietary diversity and less consumption of legumes, fruits and vegetables among children from 6–24 months in 15 African countries. Rasolofoson et al. (2018) used matching techniques to compare the dietary diversity and consumption of vitamin A and iron-rich foods of children that lived within 3 kilometers of 40 percent tree cover and those that did not. They found that children exposed to forests had 25% higher dietary diversity compared with those that did not. Not only does the extent of forest or forest change affect dietary diversity, Rasmussen et al. (2020) found that a higher number of forest patches was associated with greater fruit consumption in four countries in Africa. Most recently, Hall et al. (2022) used a combination of regression and weighting analyses to generate quasi-experimental quantitative estimates of the impacts of deforestation on people's food intake in Tanzania. They found that deforestation caused a reduction in fruit and vegetable consumption of 14 grams per day, which represented a substantial proportion (11%) of average daily intake. This paper provides evidence on the direct relationship between consuming wild foods and its positive impact on diets.

Most of the research linking forests to dietary diversity has been observational and focused on children's diets in Africa. Our paper makes a number of contributions to literature on the impacts of wild food consumption and diet quality through its use of rigorous, quasi-experimental methods and its focus on women in India.

Our analysis advances the literature by (1) using repeated monthly surveys tracing where foods were collected, thereby allowing us to observe which foods were sourced from the wild as well as seasonal changes in wild food collection and (2) using matching–a rigorous, quasi-experimental method– to isolate the causal relationship between women who consume wild foods and their diets, thereby moving beyond previous research which primarily assessed associations.

This paper uses an original, monthly-interval dataset from two rural districts in Jharkhand and West Bengal, India to characterize the impact of wild food consumption on dietary diversity. We combine statistical matching and multiple regression analysis to control for potential socioeconomic and geospatial drivers of dietary diversity and wild food consumption. These methods seek to ensure that treated and control groups are the same with respect to income, caste, crop diversity, and forest distance, so that the impact of wild foods on dietary quality is isolated. The aims of this paper are to (1) determine how wild foods contribute to dietary diversity and (2) illuminate seasonal variations in consumption of wild foods.

Findings

When comparing the average dietary diversity score (DDS) for women who consumed wild foods one or more times during the year with those who did not, we observed that the average DDS was generally higher for the women who did not consume wild foods (Fig. 1). However, the opposite pattern was observed in June and July when wild food consumption was highest. Not only did women who consumed wild foods have higher average dietary diversity, they were also more likely to have consumed dark green leafy vegetables compared to women who did not consume wild foods in June and July (Table 1).

Women primarily consumed wild foods between the months of April and July, with the highest consumption in June and July, which coincided with the lean season when crops are planted but have not yet been harvested (Fig. 2). Within the months of highest wild foods consumption, we used matching analysis and multiple regression to isolate the effect of wild foods consumption on dietary diversity. We found that in June and July, average DDS were 12% ($p = 0.033$) and 15% ($p = 0.002$) higher, respectively, among women who consumed wild foods (Fig. 3). This equates to 0.40 extra food groups in June and 0.49 in July.

The most commonly consumed wild foods were a) dark green leafy vegetables like green amaranth (*Amaranthus viridis*), water spinach (*Ipomoea aquatica*), and drumstick leaves (*Moringa oleifera*), and b) other vitamin A-rich fruits and vegetables such as hog plums (*Spondias mombin*), bottle gourd (*Lagenaria siceraria*), and bamboo shoots (*Bambusa vulgaris*). With matching analyses, we found that the odds of consuming dark green leafy vegetables in June were 5.2 times higher ($p = 0.017$) in the past 24 hours and 4.1 times higher ($p = 0.013$) in the past 7 days among women who ate wild foods compared to women who did not (Fig. 3). In July the odds were 18 times higher ($p = 0.008$) in the past 24 hours and 2.3 times higher (0.048) in the past 7 days. We found marginal evidence that wild food consumption in July decreased the odds of consuming other fruits and vegetables that are rich in vitamin A (odds 33% lower ($p = 0.09$) in the past 24 hours and 41% lower ($p = 0.09$) in the past 7 days).

We found that the consumption of dark green leafy vegetables appeared to be key to increasing the dietary diversity of women who consumed wild foods, especially at very low general levels of DDS. However, consumption of wild foods did not change women's likelihood of meeting Minimum Dietary Diversity (MDD), i.e., consuming at least five food groups in a 24-hour period. Thirty nine percent of the women in our sample never met MDD. Women who had very low DDS (2 out of 10 food groups) and did not eat wild foods consumed grains and cereals and other vegetables, whereas women who ate wild foods consumed dark green leafy vegetables, along with grains, cereals, or other vegetables. This suggests that the consumption of dark green leafy vegetables from the wild should not be seen as purely a supplementary food group added at relatively high levels of DDS. Rather, it appears key for women with poor dietary diversity.

Discussion

Our results indicate that wild foods, collected from forests and common lands, contribute to diets, especially for those with low dietary diversity during the lean season. Consumption of wild foods increased dietary diversity by 0.40 food groups in June and 0.49 in July. At an average DDS score of 3.4, an increase by half of a food group is a meaningful contribution to womens' diets in this area of India. Overall, 39% of the women in our study never met the minimum dietary diversity score over one year, pointing to a great need to address poor diets. Our findings suggest that consumption of wild foods is important to vulnerable women, particularly during June and July when crops are in the field and harvested crops from the year before are low.

In our study, wild green leafy vegetables meaningfully contribute to improving women's diets, especially at very low levels of dietary diversity. The contribution of wild-harvested green leafy vegetables to diets is particularly important since women in our study primarily sourced green leafy vegetables from the wild, rather than from the market. The price of green leafy vegetables varies seasonally, in contrast to the prices of other fruits and staple foods (Raghunathan, 2021). In India, the cost of green leafy vegetables rises steadily from January to July, at which point they are 25% higher than in January (Raghunathan, 2021). Our findings suggest that wild food harvesting provides women with a source of this nutritionally-important food group at a time when it is unaffordable at market.

Even though dark green leafy vegetables contribute little to total energy intake (Bharucha, 2010), they have a disproportionately large role in providing micronutrients like vitamin A and iron, that are commonly deficient in the diets of low-income communities. Consumption of dark green leafy vegetables has been associated with improved nutritional outcomes of people in Tanzania (Powell et al., 2013), Gabon (Blaney et al. 2009), and Benin (Boedecker, 2014). India has a rich diversity of green leafy vegetables (Avik Ray, 2022). The limited number of green leafy vegetables species that were identified in our study is likely due to limitations in translation between Indigenous languages and English.

Green leafy vegetables not only contribute key micronutrients to diets, but they may confer other health benefits such as glycemic control, immunostimulation and antioxidant activity (Kumar, 2013). They are also culturally important to Indigenous communities in India (Ghosh-Jerath et al., 2016). Wild food collection is a long-standing strategy that is already used by the poor, so it is more accessible than other top-down technological fixes like golden rice or other biofortified crops that would have to be purchased (Avik Ray, 2022).

The positive impact of wild foods on green leafy vegetable consumption was not observed for other vitamin A-rich fruits and vegetables. We observed that while women harvested other vitamin A-rich fruits and vegetables from the wild, the likelihood of consuming this food group was not higher for women who collected wild foods. We suspect that the effect of wildly collected vitamin A-rich foods was muted as women could access these foods from other sources such as markets at relatively affordable prices.

Our results may underestimate the influence of wild foods on dietary diversity since people may have been hesitant to admit that they collected wild food, especially when it was not legally sanctioned (Oliveira Chaves, 2021) and because our treatment group only included people that had consumed wild foods in the last 24 hours. The short recall period may have excluded people who only occasionally eat foods from the forest. Additionally, data on the quantity of food consumed by individuals was not assessed but will be important for future research to more accurately assess the seasonal contribution of wild foods to micronutrient intake. Furthermore, assessment of individual nutritional status using anthropometry as well as diet-related health outcomes (e.g., anemia, metabolic syndrome) would be helpful for understanding associations of wild food consumption with health status and informing policy to support seasonal gaps in diet.

Despite the monthly repeated survey, this dataset was only for one year. Although our research examined dietary trends across multiple months, future research would benefit from following the same individuals and households over multiple years. Furthermore, data across different years allows for exploration of how changes in weather patterns and land use like forest loss contribute to seasonal dietary diversity and dependence on the forest.

Future research should include more precise forest-level variables, including the types of forests (e.g., deciduous or dry shrubs) or the tree species that most contribute to diets, to make policy recommendations on what types of forests are highest priority to conserve and what types of trees to replant. In addition to physical characteristics, it is also useful to understand the dynamics of how forest rights and access affect diets. Forest rights have a long legacy in India and have been codified across different government regimes and scales, so where and what people can harvest from the forest is highly variable (Patnaik, 2007). Supplemental analysis (see supplemental material) attempted to better understand the landscape of forest rights in the context of diets, but we were limited to describing which combination of forest rights is most common in forests in our study site. The landscape of forest access rights in India is complex, and it is complicated by the variegated nature of enforcement, so we focused our analysis on whether or not people actually used the forest.

Our findings thus suggest that accessing forests and common lands can fill a critical gap in the diets of Indian women to improve diet quality, particularly among those who have the lowest levels of dietary diversity. This paper makes a significant contribution to the literature as our dataset captured the seasonal relationships between wild foods and diet in India, an important yet understudied country. India performs poorly on undernutrition indicators, exhibiting high rates of underweight (23%) and anemia (53%) among adult women (Raghunathan, 2021; World Bank 2019). Since India is home to nearly a quarter of the world's population, discovering opportunities to enhance dietary diversity has the potential to impact a large number of vulnerable people. This high-temporal resolution dataset also highlights seasonal differences and suggests that access to forests is most crucial in June and July. Our study shows the importance of forests and other common lands for improving diet quality of the most vulnerable, and it highlights the importance of policies that protect people's rights to access forests for food and other services.

Methods

Study Site

Our study site included 570 households, covering 40 villages in two districts in rainfed regions of India: Palamu, Jharkhand and Bankura, West Bengal (Figure 4). These sites have monsoons in July through October (Singh & Kushwaha, 2006) that shape seasonal food security, income diversity, and dependence on the forest and common lands (Zavaleta, 2019). These sites are home to some of the region's most impoverished people, where many live in extreme poverty, which is less than US$1.90 dollar a day (World Bank 2019). The two study sites are rural and have representation across caste-levels, including high populations of people from scheduled tribes who often face social and economic discrimination (Thorat & Newman, 2007) and are dependent on the forest (Bose, 2012; Tripathi, 2016).

Like in other parts of South Asia, villages and the surrounding areas in our study sites include both private, cultivated land, and common lands. Common lands, which are characterized by their noncultivated status, include forests, woodlots, pastures, waste lands, and other multiple-use land. From the pre-British period and even up to the mid-nineteenth century, a significant portion of land was available for communal use, including for grazing and collecting forest products and even though communal access can take many forms, usufruct rights to common lands remain common (Agarwal, 1995); see supplemental material for more details on user rights in the study site). The common areas in our site were consistently 23 ha for all villages in Bankura and 13 ha for all villages in Palamu as recorded in the most recent Census of India ((India), 2011). The forests in these two eastern states are mostly open scrub, tropical dry deciduous, and tropical moist deciduous (Champion & Seth, 1968) and patches range in size up to 228 hectares (Figure 4).

In addition to forests, common lands are a type of common pool resource that is collectively owned and uncultivated lands. They are widespread, accessed by the poor for subsistence, and may also contribute to dietary diversity, especially in India. Common lands have free standing trees that are too sparse to qualify as forest and can also include bushes and water bodies.   Like forests, it is mostly the poorest people that access common lands for their subsistence needs like collecting fodder and dung, grazing, and food and even for income generation, especially in the lean season (Chopra & Dasgupta, 2008; Jodha, 1986). Unlike forests, relatively little is known about how common lands contribute to diets and what we do know about how commons contribute to livelihoods is from the arid and semi-arid regions (Jodha, 1986) and hills and forest fringe regions (Berkes et al., 1998) in India.

Household Survey Data Collection

Twenty-three local enumerators conducted paper-based household surveys each month from November 2016 to November 2017. Villages were randomly selected from within each district based on a complete village list from the District Panchayat. Households–defined as a group of family members that share a communal kitchen–were randomly selected from complete village rosters that were created from census data and in consultation with village headmen to ensure that all households were represented. Within each household, we randomly selected one adult woman. Each interview took from an hour to an hour and a half to complete. Enumerators visited each household every month, with the goal of visiting approximately four weeks apart and on different days of the week. This effort was done so that enumerators did not over or underestimate diets given that weekly *haats*, or village markets, often fall on the same day per week. All participants were asked for consent each month to anonymously and voluntarily participate in this study. Human subjects data collection for this research was approved by the University of Michigan Institutional Review Board (protocol # HUM00103723).

Paper forms were entered into the English-language Qualtrics (Qualtrics, Provo, UT). Quality control happened at two-levels: in the field at monthly enumerator meetings where enumerators checked one another's forms and those with missing or suspicious information had to go back to the field to collect missing data with a research coordinator. Forms were also systematically checked to flag forms that were missing sections or had irregular answers that needed to be verified. Research coordinators then checked written forms for answers that were not entered correctly and also made efforts to contact households directly to verify responses.

Outcome variables

To evaluate diets, we conducted both qualitative 24-hour dietary recalls as well as 7-day food recalls. For the 24-hour diet assessment, participants were asked to list all food consumed from when they woke in the morning to when they went to sleep the day before (FAO, 2016). Participants were also asked where each food item was obtained, including if it was harvested from forests or common lands, was self-grown, purchased in the market, obtained through income compensation, bartered for, or obtained through the public distribution system. The amounts of each food consumed were not assessed.

Open-ended answers were converted in OpenRefine (Huynh & Mazzocchi, 2011) such that slang, misspelled words, or non English words were standardized. Food items were dichotomized into 10 food groups based on the Food and Agricultural Organization (FAO) and Food and Nutrition Technical Assistance II Project guidelines (FAO, 2016): 1) grains, white roots and tubers, and plantains, 2) pulses (beans, peas and lentils), 3) nuts and seeds, 4) dairy, 5) meat, poultry and fish, 6) eggs, 7) dark green leafy vegetables, 8) other vitamin A-rich fruits and vegetables, 9) other vegetables, and 10) other fruits.

Additionally, we asked people how many times in the last seven days they ate orange, red, yellow fleshy fruits or vegetables; dark green leafy vegetables; dairy products; vegetarian protein, including pulses and nuts; and non-vegetarian protein. To guide them through this process we asked them to think about each food item they may have eaten in each group and then asked them about frequency they ate it and where the food came from, as was done in the 24-hour food recall survey.

We used both 24-hour recall and 7-day food frequency data to calculate a variety of outcome variables related to dietary diversity, an important component of diet quality. First, we calculated Women's Dietary Diversity Score (DDS) as the sum of ten food groups a woman consumed the preceding day, ranging from 0 to 10 (FAO, 2021). Second, we calculated the Minimum Dietary Diversity Score (MDD), which is a dichotomous variable to assess whether women consumed at least five of the ten food groups. MDD is associated with micronutrient adequacy among women of reproductive age (Martin-Prével et al., 2015).

We also examined consumption of specific food groups which we hypothesized could be obtained from forests, including dark green leafy vegetables and vitamin A-rich fruits and vegetables.

Matched covariates

We selected matching covariates *a priori* based on those that would be associated with dietary diversity or the likelihood of consuming wild foods. Households were matched on income, caste, crop diversity, and proximity to forests. Household income was sorted into tertiles (i.e., high, medium, and low) based on the summed total of all types of income anyone in the family earned each month. Caste was parsed into two categories: scheduled tribe and everyone else. Schedule tribes have lived in and near forests since time immemorial and their culture and way of life is intimately related to the forest, including collecting food from it (Avik Ray, 2022; Tripathi, 2016). Crop diversity was a measure of how many crops a household harvested on their own land during Kharif growing season. To calculate forest proximity we used remotely sensed satellite imagery Sentinel-1 from Google Earth Engine. We used QGIS to draw a 3 kilometer radius around the center of each village to determine if forest was proximate and identified forests that had at least 10 percent tree cover in a plot of 1 hectare size as defined by the Forest Survey of India data for 2019 ((FSI), 2019).

Statistical Analysis

We performed a quasi-experimental impact evaluation to determine the causal link between wild food consumption and dietary diversity in June and July. We selected these months because that was when consumption of forest foods was the highest. To isolate the role that wild foods have on diet (Ho, 2017)for each month we first created a treatment group for women that ate at least one wild food item and a control group where households did not eat wild foods. Then we used genetic matching (Diamond Alexis, 2013) to pair each treatment household to a control household with similar covariate values. Genetic matching uses an optimization algorithm to find the best matches and has shown to perform well under diverse circumstances (King, 2019). We performed an exact match on caste and district. For the remaining covariates we achieved sufficient balance (SD<0.25, Stuart 2010, supplementary Figure 5). We used the MatchIt package (Ho, 2017) in R (version 4.0.5) to perform the matching analyses. After matching we performed regression analyses to correct for any remaining imbalances in covariates. We conducted quasi-poisson regression analyses to estimate the effect of wild food consumption on DDS. When modeling binary outcome variables (consumption of specific food groups and MDD) we used logit models and calculated odds ratios.

References

1. Agarwal, B. (1995). A field of one's own. *Cambridge Books*.
2. Avik Ray, R. R. (2022). The leafy greens of India - their diversity, pattern of consumption, and overriding implication on food and nutrition security. *Agroecology and Sustainable Food Systems 46, 432–451*. https://doi.org/10.1080/21683565.2022.2025987

3. Berkes, F., Davidson-Hunt, I., & Davidson-Hunt, K. (1998). Diversity of common property resource use and diversity of social interests in the western Indian Himalaya. Mountain Research and Development, 19–33.
4. Bharucha, Z., Pretty, J. (2010). The roles and values of wild foods in agricultural systems. Philosophical Transactions of the Royal Society B. *Biological Sciences 365*, *2913–2926*. https://doi.org/10.1098/rstb.2010.0123
5. Black, R. E., Allen, L. H., Bhutta, Z. A., Caulfield, L. E., De Onis, M., Ezzati, M., Mathers, C., Rivera, J., Maternal, & Group, C. U. S. (2008). Maternal and child undernutrition: global and regional exposures and health consequences. The lancet, *371*(9608), 243–260. https://doi.org/10.1016/s0140-6736(07)61690-0
6. Boedecker, J., Termote, C., Assogbadjo, A.E., Van Damme, P., Lachat, C. (2014). Dietary contribution of Wild Edible Plants to women's diets in the buffer zone around the Lama forest, Benin – an underutilized potential. *Food Security 6*, *833–849*. https://doi.org/10.1007/s12571-014-0396-7
7. Bose, P., Bas, A., Han van Dijk. (2012). 'Forest governmentality': A genealogy of subject-making of forest-dependent 'scheduled tribes' in India. Land Use Policy, *29*(3), 664–673.
8. Champion, H. G., & Seth, S. K. (1968). *A revised survey of the forest types of India*. Manager of publications.
9. Chopra, K., & Dasgupta, P. (2008). Nature of household dependence on common pool resources: An empirical study. Economic and political weekly, *43*, 58–66.
10. Diamond Alexis, S. J. S. (2013). Genetic Matching for Estimating Causal Effects: A General Multivariate Matching Mehod for Achieving Balance in Observational Studies. The Review of Economics and Statistics, *95* (3), 932–945. https://doi.org/10.1162/REST_a_00318
11. Food and Agriculture Organization (FAO). (2021). Minimum Dietary Diversity For Women. *Rome*. https://doi.org/10.4060/cb3434en
12. Food and Agriculture Organization (FAO). (2016). Minimum Diet Diversity for Women: A Guide for Measurement. *Rome*: *Food and Agriculture Organization*.
13. Food and Agriculture Organization (FAO)., UNICEF, WFP and WHO. (2021). The State of Food Security and Nutrition in the World 2021. *Rome: Transforming food systems for food security, improved nutrition and affordable healthy diets for all*. https://doi.org/10.4060/cb4474en
14. Food and Agriculture Organization (FAO), UNICEF, WFP, and WHO. (2018). The State of Food Security and Nutrition in the World 2018. *Rome: Building climate resilience for food security and nutrition*.
15. Forest Survey of India (FSI). (2019). India State of Forest Report,
16. Galway, L. P., Acharya, Y., & Jones, A. D. (2018). Deforestation and child diet diversity: A geospatial analysis of 15 Sub-Saharan African countries. Health & Place, *51*, 78–88.
17. Ghosh-Jerath, S., Singh, A., Magsumbol, M. S., Kamboj, P., & Goldberg, G. (2016). Exploring the Potential of Indigenous Foods to Address Hidden Hunger: Nutritive Value of Indigenous Foods of Santhal Tribal Community of Jharkhand, India. Journal of hunger & environmental nutrition, *11*(4), 548–568. https://doi.org/10.1080/19320248.2016.1157545

18. High Level Panel of Experts (HLPE), C. o. W. F. S. C. (2017). Nutrition and Food Systems. *A report by The High Level Panel of Experts on Food Security and Nutrition*.
19. Ho, D. E., Imai, K., King, G., Stuart, E. A. (2017). *MatchIt: Nonparametric Preprocessing for Parametric Causal Inference.* In Journal of Statistical Software.
20. Huynh, D., & Mazzocchi, S. (2011). Google refine. In.
21. Ickowitz, A., Powell, B., Salim, M. A., & Sunderland, T. C. (2014). Dietary quality and tree cover in Africa. Global Environmental Change, *24*, 287–294.
22. Census of India 2011 provisional population totals. *New Delhi: Office of the Registrar General and Census Commissioner*.
23. IPCC. (2019). Climate Change and Land. *An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*.
24. Jodha, N. S. (1986). Common property resources and rural poor in dry regions of India. Economic and political weekly, *21*, 1169–1181.
25. King, G., Nielsen, R.,. (2019). Why Propensity Scores Should Not Be Used for Matching. Political Analysis *27*, 435–454. https://doi.org/10.1017/pan.2019.11
26. Kumar, R., Yadav, R. K., Kalia, P., Varsha, J. (2013). Antioxidant and Nutritional Activity Studies of Green Leafy Vegetables. International Journal of Agriculture and Food Science Technology, *4*, 707–712.
27. Martin-Prével, Y., Allemand, P., Wiesmann, D., Arimond, M., Ballard, T., Deitchler, M., Dop, M.-C., Kennedy, G., Lee, W. T., & Moursi, M. (2015). Moving forward on choosing a standard operational indicator of women's dietary diversity.
28. Miller, D. C., Mansourian, S., & Wildburger, C. (2020). Forests, Trees and the Eradication of Poverty: Potential and Limitations. *A Global Assessment Report*, *39*.
29. Newton, P., Kinzer, A. T., Miller, D. C., Oldekop, J. A., & Agrawal, A. (2020). The number and spatial distribution of forest-proximate people globally. One Earth, *3*(3), 363–370.
30. Newton, P., Miller, D. C., Byenkya, M. A. A., & Agrawal, A. (2016). Who are forest-dependent people? A taxo nomy to aid livelihood and land use decision-making in forested regions. Land Use Policy, *57*, 388–395.
31. Oliveira Chaves, L., Gomes Domingos, A.L., Louzada Fernandes, D., Ribeiro Cerqueira, F., Siqueira-Batista, R., Bressan, J. (2021). Applicability of machine learning techniques in food intake assessment: A systematic review. *Critical Reviews in Food Science and Nutrition 1–18*. https://doi.org/10.1080/10408398.2021.1956425
32. Patnaik, S. (2007). PESA, the Forest Rights Act, and Tribal Rights in India.
33. Powell, B., Maundu, P., Kuhnlein, H. V., & Johns, T. (2013). Wild foods from farm and forest in the East Usambara Mountains, Tanzania. Ecology of food and nutrition, *52*(6), 451–478.

34. Raghunathan, K., Headey, D., Herforth, A. (2021). Affordability of nutritious diets in rural India. *Elsevier*.
35. Rasmussen, L. V., Fagan, M. E., Ickowitz, A., Wood, S. L., Kennedy, G., Powell, B., Baudron, F., Gergel, S., Jung, S., & Smithwick, E. A. (2020). Forest pattern, not just amount, influences dietary quality in five African countries. Global Food Security, *25*, 100331.
36. Rasolofoson, R. A., Hanauer, M. M., Pappinen, A., Fisher, B., & Ricketts, T. H. (2018). Impacts of forests on children's diet in rural areas across 27 developing countries. Science advances, *4*(8), eaat2853.
37. Rowland, D., Ickowitz, A., Powell, B., Nasi, R., & Sunderland, T. (2017). Forest foods and healthy diets: quantifying the contributions. Environmental Conservation, *44*(2), 102–114.
38. Singh, K., & Kushwaha, C. (2006). Diversity of flowering and fruiting phenology of trees in a tropical deciduous forest in India. Annals of botany, *97*(2), 265–276.
39. Thorat, S., & Newman, K. S. (2007). Caste and economic discrimination: causes, consequences and remedies. Economic and political weekly, 4121–4124.
40. Tripathi, P. (2016). Tribes and forest: a critical appraisal of the tribal forest right in India. Research Journal of Social Science and Management, *6*(6), 1–8.
41. Victora, C. G., Christian, P., Vidaletti, L. P., Gatica-Domínguez, G., Menon, P., & Black, R. E. (2021). Revisiting maternal and child undernutrition in low-income and middle-income countries: variable progress towards an unfinished agenda. *The lancet*. https://doi.org/20.2026/S0140-6736(21)00394-9
42. Vinceti, B., Ickowitz, A., Powell, B., Kehlenbeck, K., Termote, C., Cogill, B., & Hunter, D. (2013). The contributions of forest foods to sustainable diets. unasylva, *64*(241), 54–64.
43. Von Grebmer, K., Bernstein, J., Hossain, N., Brown, T., Prasai, N., Yohannes, Y., Olive, T., Foley, C. (2017). *2017 Global Hunger Index: the inequalities of hunger*. *Intl Food Policy Res Inst*.
44. World Bank. (2019). "Prevalence of anemia among women of reproductive age (% of women ages 15–49) India." https://data.worldbank.org/indicator/SH.ANM.ALLW.ZS?locations=IN
45. Wunder, S., Angelsen, A., & Belcher, B. (2014). Forests, livelihoods, and conservation: broadening the empirical base. In (Vol. 64, pp. S1-S11): Elsevier.
46. Zavaleta, J. (2019). *Women's Role in Ensuring Seasonal Food Security in Rainfed India* University of Michigan].

Figures

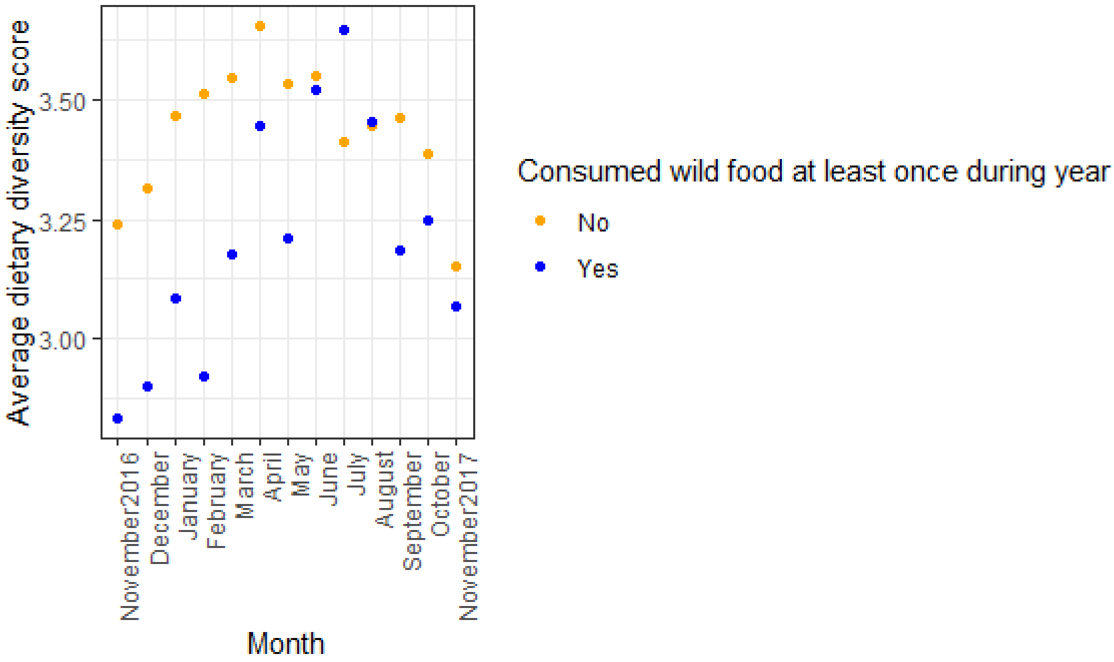

Figure 1

The average dietary diversity score (DDS) of women that did and did not consume wild foods at least one time from November 2016 to November 2017.

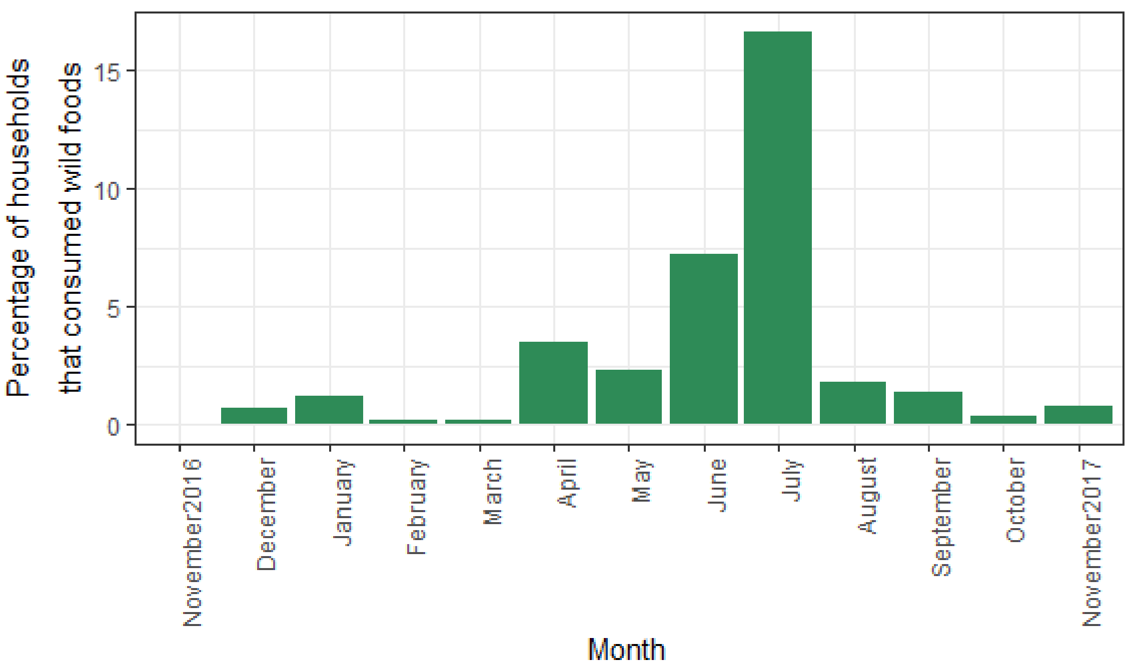

Figure 2

Percentage of households in the sample that consumed wild foods each month from November 2016 to November 2017.

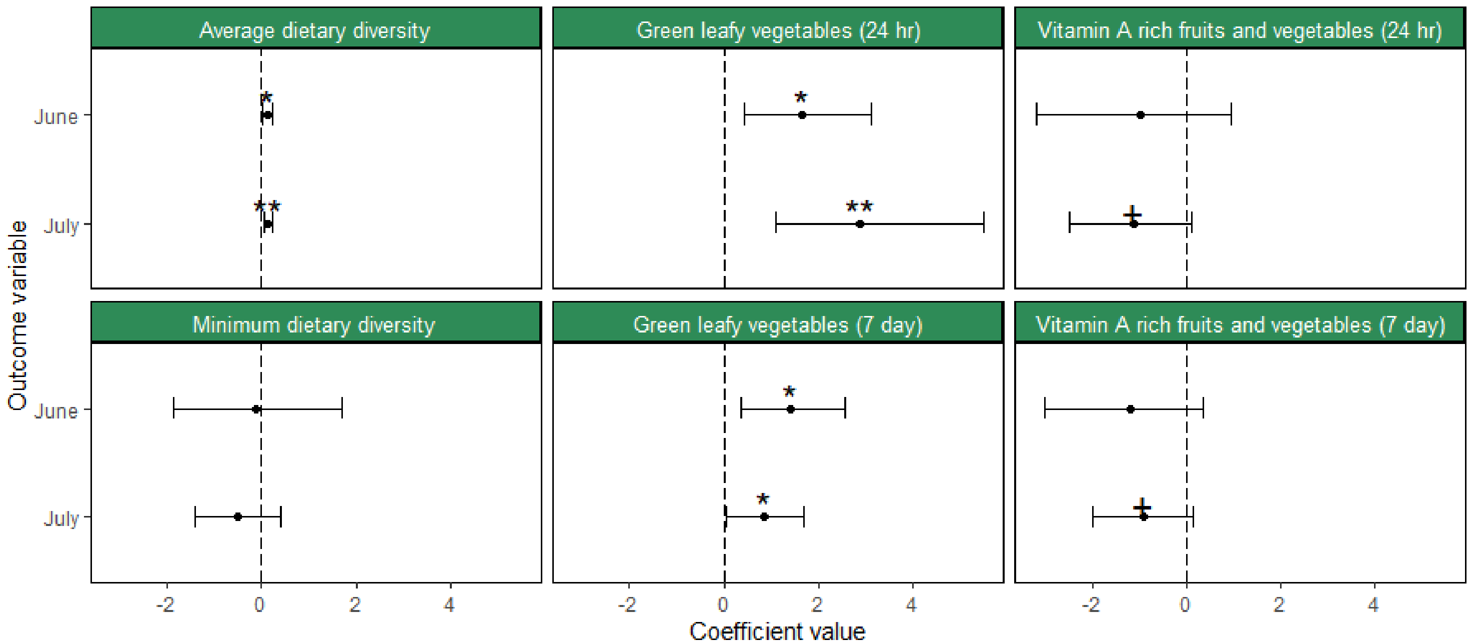

Figure 3

Comparison of the average dietary diversity score as well as consumption of dark green leafy vegetables and other vitamin-A rich fruits and vegetables of women who ate wild foods compared with a matched control of women who did not eat wild foods. Coefficient values for the dietary diversity score (DDS) are based on quasi-poisson regression models with DDS as the outcome variable, whereas logistic regression models were used to estimate Minimum Dietary Diversity (MDD) and consumption of dark green leafy vegetables and vitamin-A rich fruits and vegetables.

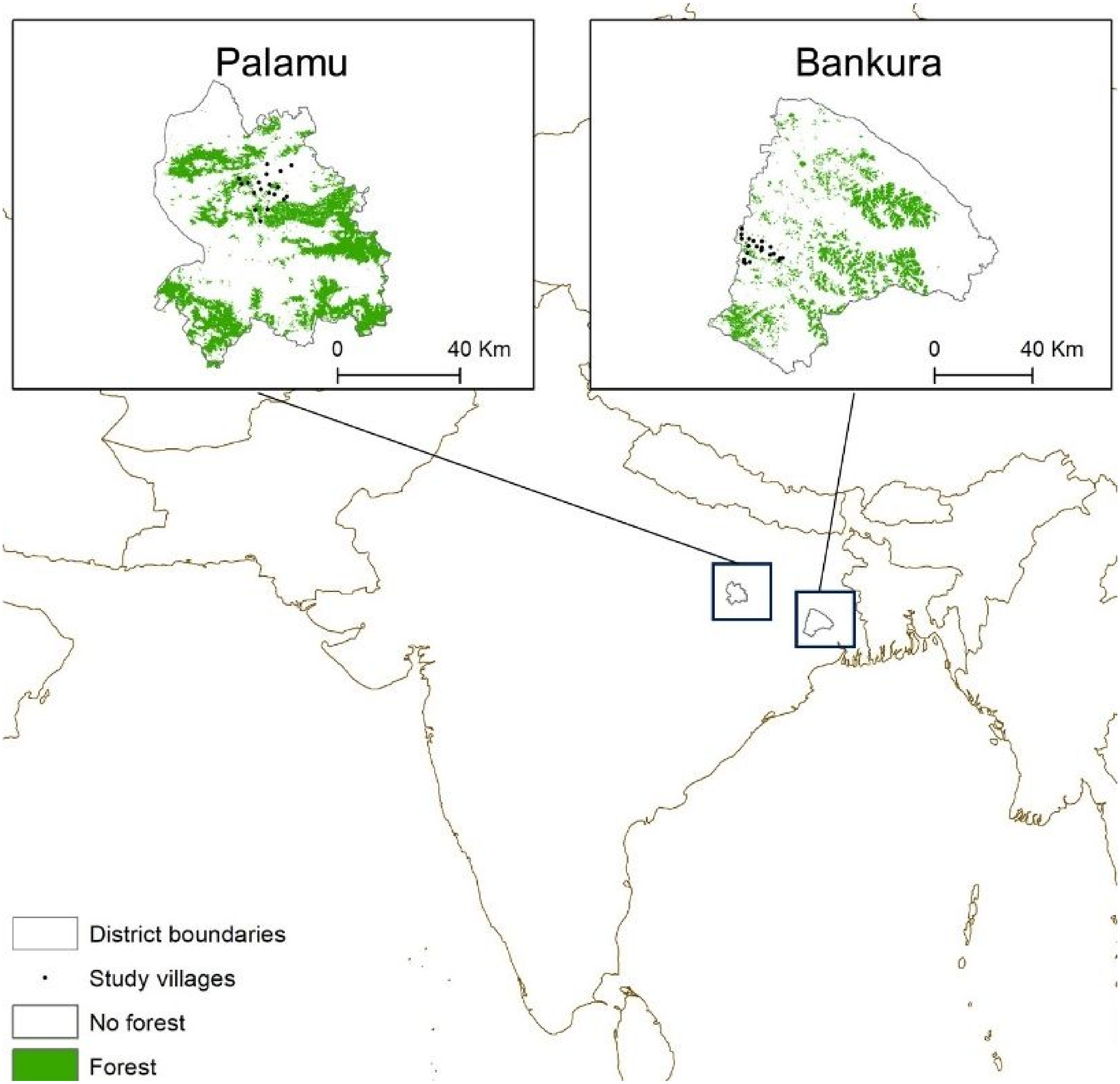

Figure 4

The selected villages and the forests that surround them in Bankura and Palamu Districts.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- 44710dataset40031r21ssq.docx