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Revisiting indigenous farming knowledge of Jharkhand (India) for conservation of natural resources and combating climate change

P Dey[1*] & AK Sarkar[2]

[1]ICAR Research Complex for Eastern Region, Ranchi Centre, Rajaulatu, Ranchi 834 010, Jharkhand, ([*]Present address: Central Soil Salinity Research Institute, Karnal 132001, Haryana), [2]Birsa Agricultural University, Kanke, Ranchi 834 006, Jharkhand

E-mail: pradipdey@yahoo.com

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As in other parts of the world, the indigenous people of Jharkhand hold important context-relevant knowledge and strategies for addressing dwindling natural resources base and climate change. The paper documents some of the collective wealth of indigenous knowledge related to agricultural practices, including land preparation/ manuring/ soil treatment, cropping systems, input management, water resource management and utilization, and soil and water conservation practices, used especially by tribal farmers of the region. Related research and policy issues essential for successful amalgamation of such indigenous knowledge in resource conservation and climate change adaptation are also discussed. It concludes that the indigenous knowledge will help to address food and nutritional security in the face of climate change.

Keywords: Indigenous Agriculture, Climate change, Biodiversity conservation, Traditional ecological knowledge, Jharkhand

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Convention on Biological Diversity (CBD) approves to respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and promote their wider application with the approval and involvement of the holders of such knowledge, innovations and practices and encourage the equitable sharing of the benefits arising from the utilization of such knowledge innovations and practices. The Intergovernmental Panel on Climate Change (IPCC) warned that warming by 2100 will be worse than previously expected, with a probable average global temperature rise of 1.8°C to 4°C and a possible rise of up to 6.4°C[1]. As temperatures continue to rise, the impacts on agriculture will be significant[2]. Many communities, notably indigenous peoples, already hold context-relevant knowledge and strategies for addressing climate change risks. Recent observations, studies and research suggest that many farmers cope with and even prepare for climate change, minimizing crop failure through increased use of drought-tolerant local varieties, water harvesting and carbon sequestration, extensive planting, mixed cropping, agroforestry practices, opportunistic weeding, wild plant gathering and a series of other traditional farming system and food production techniques. These practices point to a need to reevaluate indigenous technology and approaches as a key source of information on adaptive capacity centred on the selective, experimental and resilient capabilities of farmers in dealing with climate change. Rio Declaration on Environment and Development states that indigenous people and their communities and other local communities have a vital role to play in environmental management and development because of their particular knowledge and traditional practices[3]. The UN Declaration on the Rights of Indigenous Peoples confirms and strengthens this directive[4]. Concern has also been expressed that the effort to meet the targets laid down for the achievement of the Millennium Development Goals of UN could, in fact, have harmful effects on indigenous and tribal peoples, such as acceleration of the loss of the lands and natural resources on which indigenous peoples' livelihoods have traditionally depended or the displacement of indigenous peoples from those lands[5]. Because the situation of indigenous and tribal peoples is often not reflected in statistics or is hidden by national averages, there is a concern that efforts to achieve the MDGs could in some cases have a negative impact on indigenous and tribal peoples,

*Corresponding author

while national indicators apparently improve. In anticipated responses to climate change and in combating the climate change impacts already being experienced by many indigenous peoples and communities, governments and other actors must engage comprehensively and inclusively with indigenous peoples, ensuring their full and effective participation and honouring the right to self determination and the principle of free, prior and informed consent as set out in the United Nations Declaration on the Rights of Indigenous Peoples[6].

Despite good amount of rainfall received in Jharkhand (Table 1), most of the fields are monocropped usually with upland rice with very poor productivity (less than one ton) and we call it 1t agriculture (one ton agriculture). The annual normal rainfall in Jharkhand is 1,400 mm. The total utilization of surface and ground waters achieved in the state so far is 47,760 lakh m^3 & 13,280 lakh m^3, respectively. The unutilized water resources work out to be surface water 1,90,130 lakh m^3 (79.9%) and ground water 36640 lakh m^3 (73.4%). This is not a happy situation so for as the useful utilization of the precious water resources is concerned and speaks of 'scarcity amidst plenty'. This has created vicious cycle of selling a portion of rice and keeping another portion for household consumption. The money earned from the sale of portion is used for purchase of goat, chicken, etc. After few months when the saved household portion of rice gets exhausted, the goat and hen/cocks are sold to meet household consumption. When those also get exhausted then they migrated to nearby town for working as labourer. The major constraints of non-availability of irrigation water is run off loss of rain water due to sloppy and undulating terrain, poor quality of water and soil conservation methods, low soil depth with poor water holding capacity and solid rocks below soil surface which check the infiltration of rain water. Soil erosion due to undulating topography is another important factor that limits the agricultural production.

Table-1 District wise mean rainfall (10 years mean) in Jharkhand

Districts	Rainfall (mm)	S.No.	Districts	Rainfall (mm)
Bokaro	1145.3	12	Jamtara	1328.8
Chatra	1078.7	13	Kodarma	1125.1
Deoghar	1420.7	14	Latehar	1329.9
Dhanbad1	223.5	15	Lohardaga	1137.4
Dumka	1358.5	16	Palamu	1257.1
East Singhbhum	1321.6	17	Pakur	1730.1
Garhwa	1237.4	18	Ranchi	1388.6
Giridih	1095.3	19	Sahebganj	1371.4
Godda	1100.2	20	Saraikela	1276.9
Gumla	1521.5	21	Simdega	1381.8
Hazaribagh	1138.2	22	West Singhbhum	1253.4

Methodology

Indigenous farming knowledge (IFK) is the actual knowledge of a given agrarian population that reflects the experiences of agriculture and associated practices based on traditions and incorporates more recent experiences with modem technologies. Local people, including farmers, landless labourers, women, rural artisans, and cattle rearers, are the custodians of rich indigenous knowledge systems – systems of knowledge, practice and belief developed over long time periods and passed down by cultural processes through the generations[7]. Over centuries, indigenous people have learnt to avert the effect of climate change through traditional knowledge systems[8]. There is a vast wealth of IFK available from small scale farmers, especially the tribal ones who are highly dependent on local lands and resources for their families' nutritional and survival needs of several tribes of Jharkhand primarily belonging to *Ho*, *Santhal*, *Munda*, *Oraon*, and *Lohra*. The study was based on questionnaire-based personal interview in and visit to different field sites as well as group interaction. Similar practices were grouped into one category. The paper enlists and discusses some of the IFKs, mainly group held knowledge, as collected through a survey undertaken among indigenous farmers in different blocks of Jharkhand state.

Jharkhand state is spread over 7,971 655 ha geographical area. Within this, the area suitable for agriculture is about 2,852,160 ha, the gross cropped area is about 2,419,200 ha, the upland area comprises about 1,339,200 ha and the lowlands about 1,065,940 ha. The major constraint for agriculture is that more than 80% (about 2,287,460 ha) of the arable lands are rainfed. The state is dominated by Alfisols and major landscape types occurring in each geological formation include: Archean Granite and Gneiss landscapes (Deoghar, Dumka, Giridih, Hazaribagh, Ranchi, Lohardaga and Gumla districts); Dharwar landscape (Giridih, Gumla, Singhbhum and Palamu districts); and Gondwana landscapes (Dhanbad and parts of Hazaribagh and Palamu districts). These landscapes are comprised of hilly terrains, undulating plains, plateaus and valleys. Hilly terrains are largely under forest cover and not used for agricultural activities due to their steep slopes, shallow rooting depth, severe soil erosion and low to medium available water capacity. The other three areas are used for agricultural activities. The soils of the undulating plains, plateaus and valleys are shallow (25- 50 cm), deep (100-150 cm) and very deep (>150 cm), respectively, well to moderately to poorly drained, slightly acidic in nature, low organic matter and low to medium to high available water holding capacity. The majority of soils have sloping and undulating topography, stoniness (presence of stone), and poor water holding capacity, as well as being drought prone and moderately eroded, with soils in some parts of state being poorly drained. The majority of plateau soils are planted with paddy, maize, minor millets, pulses and oilseed (niger crop) in block rotation, and only paddy cultivation occurs in terraced/valley lands. In a broad sense, the soils of Jharkhand state have been classified into two broad groups as per revenue class and productivity, namely, *Tanr mitti* (Upland soils) and *Don mitti* (Lowland soils). The *Tanr mitti* is further divided into *Tanr* I (Bariland), *Tanr* II (Typical upland) and *Tanr* III (Gravel, stony, morram land). The *Don mitti* is divided into Don I (Garha), Don II (Tarkha) and Don III (Chatar) as per hydrology (Table 2).

Results and discussion

The outcome of our survey which embodied indigenous knowledge related to land preparation/manuring/soil treatment, cropping system, input management, water resource management and utilization, and soil and water conservation practices is presented below:

Land preparation/manuring/soil treatment

The usual practice is primary tillage in the form of 3-4 ploughings, done at relatively long intervals from January to May. For direct seeded rice, cow dung is powdered and mixed thoroughly with the soil after broadcasting of rice seeds and then planking (leveling the land surface after cultivation with wood log) is done. This practice helps in better mineralization of nitrogen from the manure for uptake by the young plants, since nitrogen mineralization is essentially a microbial mediated process and with powdering and mixing, the process occurs faster. Moreover, this helps to improve the water holding capacity of the soil and under field capacity moisture conditions the mineralization was found to be higher when the nitrogen was from organic sources[9]. Another practice we documented, pre-sowing manuring for transplanted rice, is done by keeping dried cow dung mixed with ashes in the field at different places in basketsful or heaps and, at the time of final ploughing, properly spreading the heaps over the field. The indigenous farmers also burn cow dung cakes in nursery plots of finger millet (*Eleusine coracana*) prior to the first tillage operation, as part of the seed bed preparation. Further fresh cattle dung is mixed with water and sprayed over the standing rice fields. The practice of raised bed planting for vegetables reduces the wetted area by 30-40% compared with conventional flat bed planting. One of the main concerns of sustainable agriculture is depleting carbon content of the soil vis-à-vis declining soil fertility. Such practices help in achieving positive carbon sequestration, thereby address sustainability of farming.

Cropping systems

The following cropping systems were found to be predominant among the tribal community: legume-based mixed and intercropping practices are common, for example with combinations like pigeonpea + rice, pigeon pea + blackgram, pigeon pea + finger millet, pigeon pea + maize, cowpea + rice, gram + wheat, gram + linseed, gram + mustard; farmers practice crop rotations, including rice-gram, rice-lentil, rice-wheat-mungbean, rice-pea, groundnut-wheat, maize-wheat and different vegetables- and potato-based cropping systems; and *Paira* cropping in rice lowlands: *Lathyrus* seeds are broadcast in standing rice when soils are saturated; the crop gives a good yield without irrigation. A close look in the above systems indicates that most of the tribal farmers include legumes in their planting which contributes to biological nitrogen fixation in soil and thus enriches the soil. Another unique feature of these systems is inclusion of pigeon pea (*Cajanus cajan*). Researchers has also documented that locally adapted varieties of pigeon pea uniquely combine optimal nutritional profiles, high tolerance to environmental stresses, high biomass productivity and nutrient and moisture contributions to the soil[10]. In the face of climate change, such practices will act as insurance for the farming community.

Input management

Preparation of organic manures/composting

The dung of the animals used as fuel and manures produced from house waste is kept in a pit near the

Table-2 Land classification by revenue class, local class and by hydrology in Jharkhand state

Revenue class (Group)	Sub-group	Local name	Category by Hydrology	Description
Tanr land	Tanr III	Tanr	Upland	Sloppy and gravelly lands, shallow in depth, low water holding capacity and with poor soil fertility. The lands are generally on the upper most topo-sequence on the landscape.
	Tanr II	Tanr/Gora land	Upland	Gentle sloppy to sloppy land, adjacent to the village with good soil depth, coarse texture, poor in organic matter, low water holding capacity, erosion prone and acidic in nature.
	Tanr I	Bari land	Upland (Kitchen Garden land	Land immediately adjacent to the homestead, used for vegetable, maize and rice seedling growing.
Don land	Don III	Chater/ Chaura/ Badi (3 number)	Drought prone shallow lowland	Transitional land between tanr and don categories moving from shallow to deep soils, greater bund heights, flat surface, higher water holding capacity. Suitable for short duration crops. Almost same physiographic position as the Tanr I.
	Don II	Tarkha (2 number)	Favorable shallow lowland	These are the best lands for rice cultivation and for follow up crops. This land rarely faces drought. Major rice production in Jharkhand comes from these lands.
	Don I	Garha/ Ghoghra (1 number	Favorable lowland to medium deep	Lowlands with water accumulation up to 40-50 cm. Lowest in topo-sequence and suitable for long duration rice crop.

homes. The heap method of composting is followed. Forest litter, animal bedding material, and vegetable wastes are all utilized for composting. Composting of farm waste with the help of earthworms is practiced by some of the farmers. A few farmers use compressed cakes of plant material and flowers as manure; application of *mahua* (*Madhuca indica*) cake, *neem* (*Azadirachta indica*) cake, and *karanj* (*Derris indica*) cake and leaves and flowers along with farm yard manure (FYM) is practiced. Amongst these cakes, that of *karanj* (Fig.1) was found to be most popular with tribal farmers. Some farmers also apply wood ash.

Herbicides, pesticides and other inputs

Farmers are not aware of herbicide application, and hand weeding is practiced for the *kharif* crop to control weeds. Burying of the weeds is often followed. Some of the farmers apply a mixture of kerosene oil or burnt diesel and *karanj* oil to control the weeds. Termite attacks can be severe, and farmers adopt the method of water logging to control these pests. Deep summer ploughing, planking and leveling is done after every rain. These practices help to keep the land weed-free. Such non-chemical weed management will help in reducing pesticide load of the soil without reducing productivity. Application of *neem* and *karanj* cakes, which the farmers of Jharkhand have been practicing since time immemorial, is very important, especially for conditioning the light textured acidic soil of Jharkhand, since these manures besides their nutrient values also provide a safeguard for solanaceous vegetables (especially tomato and brinjal) against bacterial wilt caused by *Ralstonia solanacearum*. With more and more reports about pesticide resistance pouring in from different parts of the world, such practices, if promoted, will be helpful for addressing pesticide resistance and reducing pesticide load of soil other regions also.

Water resource management and utilization

By the 2050s, freshwater availability in Central, South, East, and Southeast Asia, particularly in large river basins, is projected to decrease dramatically. However, during the survey, it was observed that water resources are better protected in the hands of indigenous people. This is because these people are among the first to face the direct consequences of climate change, due to their dependence upon, and close relationship with, the environment and its resources. In any case, climate change exacerbates the difficulties already faced by indigenous communities, including political and economic marginalization, loss of land and resources, human rights violations, discrimination and unemployment[11].

Water harvesting and recycling

Plot to plot bunding (preparation of small field dyke) and terracing of sloping land is commonly undertaken by the farmers we interviewed. Summer ploughing and mulching of crop residue is also done to conserve soil moisture. Bamboo drips or small spring water structures are used to store water in the rainy season, to be utilized for irrigation in winter crops. Water from the fields is harvested by constructing a bund in the lower areas or by deepening the lower parts of the land and creating ponds for water storage. The plot size is generally less than 0.2 ha and the size of the ponds varies from 20x10x1 to 30x30x5 m. The water stored in these ponds is used for irrigation of the succeeding *rabi* (winter) crops like potato and mustard. Bamboo pipes with holes at certain intervals are used to distribute the water. Experiments conducted at ICAR research station at Ranchi showed that small rainwater harvesting structure called *Doba* (Fig.2) can be effectively used for establishment of agroforestry in upland which comprises more than 70% area in Chotanagpur plateau region[12]. Although on an average 140 cm rainfall is received in Chotanagpur plateau, water is the single most important constraint in establishment of agro-forestry. In the process, each *Doba* structure with 4.5 m^3 capacity (3.0 m length, 1.5 m breadth and 1.0 m depth) has been constructed for harvesting of rainwater before the onset of monsoon. The inner sides of the *Doba* structure were lined with 200 µ black polythene sheet. The excavated soil was used to make a small bund covering the black polythene sheet. Rest of the soils were used to make bunds surrounding the group of 12 budded/grafted trees or MPTs. Clear rainwater is allowed to store in the *Doba* structure during monsoon months. Finally in the month of October, the *Doba* structure was covered with thatch made of *hogla* (*Typha elephantina*) (Fig.3). At fortnightly interval, *neem/karanj* oil is poured in the Chotanagpur plateau region to reduce evaporation. The *Doba* structure constructed could be used for three years. It was observed that these *Doba* structures were helpful in providing lifesaving irrigation for establishment of orchard under Chotanagpur plateau region[13].

Earthen bunding

This is an age-old practice in which farmers level their lands and prepare earthen bunds across the slopes; they strengthen the bunds with locally available hardy weeds and bushes. These bunds have been found to be very effective for soil, water and nutrient conservation. The bund height and width varies from 0.5 to 1.0 m in land having a slope up to 5% and from 1.0 to 2.0 m in land with slopes above 5%. Plot size varies from 0.2 to 0.4 acres. Depending upon the shape and size of the bund the cost for the construction varies. Bunds are maintained occasionally before the *monsoon/kharif* season.

Stone bunding

A good example of indigenous soil and water conservation practice in Jharkhand is creation of stone bunding, which essentially involves constructing bunds with locally available stones across the land slope. These bunds have been found to be very effective for soil, water and nutrient conservation and for safe storage and sequestration of excess water from the fields in places of undulating terrain especially in the high rainfall areas.

Stone-cum-earthen bunding

People have continued to innovate in the face of change and stone-cum-earthen bunding has evolved from earlier structures. In this practice, stone bunding is constructed at the base followed by earthen bunding on the top. Sometimes, in stone bunding, soil is filled in to work as a cementing agent. The height of the bund varies from 0.5 to 2 m and the width is up to 1 m. Another practice is stone-cum-vegetative bunding, in which tribal farmers residing in forest villages make stone bunds in their fields and, to stabilize these bunds, they plant some trees and sometimes hardy bushes on the bunds. This is done with the help of local tools and very little maintenance is required. The different bundings are essentially built to address stabilization of land in the face of excess runoff due to aberrations of rainfall. Other authors have also observed that in Africa, South Asia and in other parts of the world, traditional societies have developed a diversity of local water harvesting and management regimes that still continue to survive[14].

Water management from rivulets

This recent practice which is an excellent example of adoption to address drought has evolved from the experience of the farmers of Jharkhand and has been used only for the last 8 yrs. The seepage water from the fields which flows in small rivulets is collected by constructing a bund in the lower reaches of the rivulets and where water can be stored. Depending upon the availability of drainage water, similar bunds may be constructed at many points along the length of the rivulets. This stored water is reused very judiciously for typical *rabi* (winter) crops (mixed cropping of cabbage/cauliflower + mustard + tomato) grown in beds and irrigation is provided for each bed mainly by carrying water in small drums. The farmers harvest all the three crops simultaneously in the *rabi* season.

Low cost structure to address soil and water erosion

Grassed waterways

Grassed waterways are constructed by small and medium-scale farmers both on an individual and a community basis. They were developed by the farmers based on their experience and have been used for the last 10 yrs. The waterways are constructed before rains and some hardy weeds are grown on the sides to make the structure more stable. Excess water from the rice fields is allowed to pass through these structures. The width of the waterway is up to 1 m and the depth is 0.5 to 0.7 m. This is almost stable and easy to maintain. These grassed water-ways provide safe guard against soil erosion by diverting excess runoff through them.

Spur structure

Spur structures were developed by the farmers and have been used over the past 10-15 yrs. In this practice, after transplanting rice, the farmers prepare spurs (temporary barrier like structures) with the help of locally available materials like forest woods, in locations where there is runoff water, in order to divert the water flow. Some stones are also placed strategically to reduce the flow of water and avert soil loss. Some grasses and weeds are also placed on these structures in order to make them semi-permanent. This technology is mainly practiced in the rice fields of the plateau and hilly regions, particularly during the *kharif* (rainy) season. The average slope of the land varies from 2-3%. The cost involved is very small, and maintenance is done every year by the individual farmers.

Brushwood waste weirs

These weirs have been developed and used by the farmers for the last 10-15 yrs. The farmers strengthen the bunds before the onset of monsoon. In some places waste weirs and stones are placed on the bunds to facilitate excess water flow and also to support the bund against heavy water flows. These structures, like the spurs, are mainly constructed in the plateau and hilly regions, particularly during *kharif* (summer) season in rice fields. The average slope of the plot is about 2-3% and the bund height and width varies from 0.5-1.0 m. With changing climate, the rainfall is getting erratic and temporally uneven. Large runoff generated from such aberrations of rainfall due to changing climate can be effectively addressed through establishment of such structures to decrease runoff volume and thereby prevent erosion.

In-situ moisture conservation

In an age-old practice followed by the tribal farmers, linseed/gram seed is broadcasted in standing rice crop just before the rice is harvested. In this practice, the farmers select only the rice fields that have sufficient moisture. During harvesting of paddy, the seeds of linseed/ gram automatically penetrate the soil and germinate in due course. The remaining biomass of the paddy acts as a mulch for the growing linseed/gram. These crops perform poorly as compared to their normal cultivation, but the farmers get some yield minimal effort. Sometimes, if there is some rain during the growth period and is some nitrogenous fertilizers are applied they harvest a good yield. Repeated dusk ploughing and morning planking to sequester the dew helps in seed germination under rainfed conditions. Another practice is planking in the standing wheat crop at crown root initiation (CRI) stage with the help of *desi* (local) cow or ploughs for soil compaction, in order to increase the capillary rise in rainfed wheat. These water harvesting systems and moisture conserving practices have been central to the diversification of food production. Experiments conducted at ICAR research station at Ranchi also showed that half moon terracing coupled with paddy straw mulching has improved the yield and reduces the sun burning of litchi cv. Shahi[15].

Mulching

Crop mulching has also evolved from the experience of the farmers and has been in practice for the last 20 yrs. Tree leaves and paddy straw are used as mulch materials for raising ginger. Ginger seed is sown in the month of May before the onset of the monsoon and the field is then covered with mulch. This conserves the soil moisture and simultaneously keeps the soil cool which provides favourable conditions in initial stage of germination and seedling emergence of ginger. Later on, these mulches act as organic matter to enhance the crop. This practice is particularly important given that a climate change impact potentially significant to small farm production is loss of soil organic matter due to soil warming. Higher air temperatures are likely to speed the natural decomposition of organic matter and to increase the rates of other soil processes that affect fertility.

Agroforestry techniques

In the home gardens of Jharkhand, jackfruit has been a common fruit crop over the past several centuries. These types of fruit-tree based multi-tier systems were found to conserve soil organic carbon better[16]. Many farmers grow crops based agroforestry designs and use shade tree cover to protect crop plants against extremes in microclimate and soil moisture fluctuation. The raised planting beds, mounds, and ridges often found in traditional systems serve to control soil temperatures and to reduce waterlogging by improving drainage[17,18]. Given the light texture soil of Jharkhand, any *in-situ* process which can conserve extra moisture was found to favour better growth for establishment of agroforestry—one such example is sunken pit method (Fig. 4) of planting[19]. Tribal farmers of Jharkhand employ resource conserving farming practices with the utmost prudence (Table 3). In fact, many researchers have opined about the benefits of time and effort needed for collaboration with Indigenous Peoples and local communities to effectively and ethically include their knowledge, perspectives and needs as key elements of research, planning, decision-making, training and monitoring[8,20]. Such indigenous systems have been managed in ingenious ways, allowing small farming families to meet their subsistence needs in the midst of environmental uncertainty and variability with little dependence on modern agricultural technologies[21]. However, it is worthwhile to remember that while short-term adaptation activities are underway, resource and capacity constraints are limiting the implementation of long-term adaptive strategies for indigenous farmers.

Right up to the present time, well into the first decade of the 21st century, throughout the world there are millions of smallholders, family farmers and indigenous people practicing resource-conserving farming, which is testament to the remarkable resiliency of agro-ecosystems in the face of continuous environmental and economic change, while contributing substantially to food security at local, regional and national levels[22]. It is important to note that such actions of indigenous people are important initiatives in the face of climate change, but they will only be successful if they are integrated with other strategies, including disaster preparation, land-use planning, environmental conservation and national plans for sustainable development[11]. Indigenous perspectives – about the interconnectedness of life, the importance of a long-term view of the

Figs. 1—4 *Karanj* under field conditions, 2 Rain water collected in black polythene lined, *Doba*, *3 Doba* covered with *hogla* thatch to check evaporation, and 4 Sunken pit promotes better growth

Table-3 Toposequential land use prevalent with tribal farmers of Jharkhand

Type	Land situation	Soil	Crop
Rainfed gravelly and eroded uplands	High to medium slope	Light textured red, highly acidic in reaction, very low water holding capacity, sandy and stony, very low in available N, P and K	Niger, leguminous trees (block plantation)
Rainfed gravelly uneroded uplands	High to medium slope	Light textured red, highly acidic in reaction, low water holding capacity, sandy and stony, and low in available N, P and K	*Gora* (upland) rice, fingermillet, *gundli,* maize, niger and pigeonpea
Partially irrigated uplands (locally called as *Barilands*)	Medium slope	Light textured sandy and semi-gravelly, acidic in reaction, and have low water holding capacity, low to medium in available N and P and medium in K	Vegetables
Rainfed slightly eroded midlands	Medium slope	Sandy loam in texture, acidic in reaction, have low water holding capacity, low in available N and P and medium in K	Rice in *kharif* (rainy) season and vegetables in *rabi* (winter) season
Partially irrigated medium lands	Medium slope	Heavy textured, low in available N and P and medium to high in K, medium water holding capacity	Rice in *kharif* (rainy) season and vegetables in *rabi* (winter) season
Irrigated medium lands	Lower slope	heavy textured, weakly acidic in reaction, low in available N, medium in P and K	Vegetables
Rainfed lowlands	Lower slope	Heavy soils, good water holding capacity and high fertility status	Rice
Partially irrigated lowlands	Lower slope	Heavy soils, good water holding capacity and good fertility status	Rice followed by vegetables; *Paira* cropping of linseed/peas
Irrigated lowlands	Lower slope	Heavy soil, medium in available N and P and high in K	Rice followed by vegetable/wheat
Rainfed deep lowlands	Lower slope	Heavy clay-loam soils, good fertility status, medium in available N and P and high in K; neutral pH; water logging prevail up to January-February	Rice followed by vegetable

future, the linking of human health and well-being to the health of the environment as a whole – need to be infused into western urbanized society in ways that allow understanding and consideration[23]. In the International Expert Meeting on Indigenous Peoples and Climate Change, organized by UNU's Japan-based Institute of Advanced Studies (UNU-IAS) in conjunction with the UN Permanent Forum on Indigenous Issues (UNFII) and the North Australia Indigenous Land and Sea Management Alliance (NAILSMA)[6].

Conclusion and policy implications

Many of the tribal practices in the world are being vanished over the years due to rapid urbanisation and Jharkhand is no exception. Hence, it is utmost essential to document all the information related to protection of natural ecosystem and local environment available among the indigenous communities before they are lost. Different strategies, especially in allowing adaptation and resilience to climate change, being practiced has been described. Many of these practices like use of *karanj/neem* cakes for cultivation of solaneceous vegetables can be directly adopted. Some of the structures like stone-cum-earthen bunding and brushwood waste weirs can supplement costly engineering structures. Some of these practices have been evolved to address drought which may be any of the three types, viz., late onset of monsoon, long dry spell during the monsoon or early withdrawal of monsoon.

This research clearly demonstrates that indigenous people and their knowledge are central to the adaptive changes using available natural resources essential to face the world's changing climate. Planners and policy makers have yet another tool and dimension from which to formulate a participatory research agenda by seeking opinions and participation of indigenous populations. Assessments of indigenous knowledge suggest and urgent need for building on local and traditional knowledge relating to managing natural resources and climate risk. Successful amalgamation of the knowledge and practices of indigenous people requires their consideration together with other developmental aspects in a holistic manner. Toposequential farming models described hear readily lend to modification and adaptation for specific conservation and crop production needs. It is imperative to initiate participatory research involving tribal farmers in order to develop adoptable technology that will enable mitigation of many natural resource problems, especially related to soil and water conservation practices and climate change. Moreover, region-specific amalgamated technological prescriptions refined with targeted policy analysis are required for effective implementation and obtaining positive outcomes within a finite time horizon. However, to ensure scientifically credible results amalgamated with traditional knowledge and building capacity, participatory monitoring of the natural resource base from time to time is also essential. Policies should be adopted that transform the custodians of natural heritage - the indigenous populations - to the status of precious partaker in vigilance and enforcement enterprise with authorized establishment. This will provide a strong foundation for pragmatic policy formulation on natural resource conservation and combating climate change.

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