Production and conservation of medicinal plants in understorey of degraded Chir pine forests using sustainable techniques

Chandra Shekhar Sanwal, Raj Kumar, Sneha Dobhal, Sushma Kerkatta and S. D. Bhardwaj*

In general, little emphasis is given on the production of medicinal plant species for sustainable harvest and conservation in the understorey of degraded forests. For instance, forests like chir pine which are not managed to grow any medicinal plants, offer an opportunity to produce and conserve native medicinal plants. This article highlights a study focusing on the production of medicinal plants in association with Chir pine forests, involving sustainable management techniques like minimum tillage and selecting suitable aspects for the sustainable harvest and conservation of plants under the canopy of trees. The medicinal plants were grown on three topographical aspects – Northern, North-Western and Western by adopting three tillage depths, viz. minimum (0 cm), medium (up to 10 cm) and deep tillage (up to 15 cm), in open and below tree canopy conditions. From yield and economic point of view, Andrographis paniculata, Mucuna pruriens, Solanum khasianum and Spilanthes acmella were found to be better yielding and more remunerative in comparison to Withania somnifera, Cymbopogon nardus and Ocimum basilicum, when grown outside the tree canopy adopting deep tillage on the Western aspect in Chir pine forests. The study can also be applicable to the other parts of the country to produce and conserve native medicinal plant species using sustainable management techniques like minimum tillage in blank patches or understorey of the degraded forests.

Keywords: Chir pine, degraded forest, medicinal plants, production and conservation, sustainable management.

TODAY there is a worldwide growing demand for high-quality, certified organic herbal products. This has created an unsustainable harvesting of medicinal and aromatic plants (MAPs) and other products from natural forests. The commercial production of MAPs fills this market by providing green health alternatives to another eco-friendly product for both domestic and industrial uses[1,2]. However, conservative estimates put the economic value of medicinal plant-related trade in India to the order of Rs 1000 crores/year[3], and the world trade over US $60 billion[4]. At present, these resources from the wild are depleting rapidly, and several medicinal plants are threatened with the extinction. In spite of this, most of the commercial medicinal plants are collected from the wild either legally or illegally, from all over the Himalaya and other parts of the country for various purposes, while only a small number of species is cultivated[5]. On the other hand, there are several native medicinal plants (e.g. *Adhatoda vasica* and *Murraya koenigii* in sal forests) which grow, die and regenerate naturally inside the forest every year, but never get attention for their sustainable harvest and conservation. Also, many medicinal species are shade-tolerant climbers, shrubs and herbs that can be easily grown in the understorey of different forests. They also possess the ability to grow in poor soils and under low rainfall and moisture conditions, and thereby can assist in the replenishment of green cover of the existing degraded forests. Hence, there is great scope of production and conservation of native MAPs in the understorey of degraded forests without reducing area under agriculture production for meeting the food priorities of the ever increasing population of the country. Keeping in view the above facts, a study has been presented regarding the development of sustainable techniques for improving the productivity of degraded forests through the introduction of medicinal plants.

Chandra Shekhar Sanwal is in the Uttarakhand Forest Department, Dehradun 248 001, India; Raj Kumar is in the ICAR-Indian institute of Soil and Water Conservation, RC, Vasad 388 306, India; Sneha Dobhal and S. D. Bhardwaj are in the College of Forestry, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan 173 230, India and Sushma Kerkatta is in the Department of Forestry, Sarguja Vishwavidayalaya, Ambikapur 497 001, India.
*For correspondence. (e-mail: rajcswcrti@gmail.com)

Need for production and conservation of medicinal plants

Today, the understorey of existing degraded forests is infested with exotic weeds like *Lantana camara*, *Eupatorium* *odoratum*, *Parthenium hysterophorus*, *Cassia tora*, *Hyptis suaveolens*, etc. Other invasive species are also spreading at a rapid pace and their eradication is critically important. The blank patches in the understorey of degraded forests are rapidly and easily invaded by these exotic weeds in the absence of any understorey vegetation belonging to the native plants, even after conducting successful weeding operations on the forest floor. So there is a need to utilize the existing blank patches of the understorey of degraded forest land or monoculture plantations. The cultivation of medicinal plants has been an age-old practice in China, under the 'silvo-medicinal' system. For instance, in North-East China, ginseng (*Panax ginseng*) and other medicinal plants are grown in pine (*Pinus* spp.) and spruce (*Picea* spp.) forests; while in central China, many medicinal plants are planted with *Paulownia tomentosa*, and in Southern China medicinal herbs are often planted in bamboo (*Bambusa* spp.) and Chinese fir (*Cunninghamia lanceolata*) forests[6]. In Australia, the practice to grow *Pinus radiata* and *Pinus pinaster* with subterranean clover is being refined for the development of efficient systems to control stream salinity in catchment areas, as well as soil salinity levels on farms[7].

Development of sustainable techniques

The topographical aspect affects the climate of a site which, to an extent, is dependent on its relation to the sun's course and the prevalent wind in the hill regions. Moreover, this aspect is influential in hilly regions and creates large differences in microclimate that can be used as criteria for selecting medicinal and aromatic plants depending on its light requirement. Direction of planting a crop with respect to tree row also plays an important role in the growth and yield performance of a field crop[8]. East–West direction of tree row causes least negative influence on crop yield than North–South direction of tree row. Malik and Sharma[9] observed higher population and growth parameters of crops on the Northern side than the Southern side in a plantation. Tillage is mainly concerned with the physical and nutritive conditions of the soil that controls weed growth. Tillage makes the soil more fertile and therefore, can be used in the management of pine stands[9]. It is worthwhile to mention here that minimum tillage concept has already been formulated realizing the importance of weed control as the central objective[10]. Indeed, minimum tillage depth can be used as a sustainable management input with respect to the cultivation and conservation of medicinal plants under pine stands of mountainous regions[11,12]. Moreover, Kothari *et al.*[13] in a field experiment during 1991–2001 under semiarid tropical conditions of Hyderabad, studied the effect of tillage depth (15–30 cm) and plant population density (20, 40, 60 and 80 plants/m^2) on root morphology, yield and quality, and cultivation economics of *Withania somnifera*. So management input of deep tillage can be applied to MAPs, where official part is generally roots like *Withania somnifera*, etc. However, minimum tillage depth can be more effective in rainfed mountainous regions, across the world in the understorey of degraded forests, where minimum tillage coupled with accumulation of leaf litter results in moisture conservation and low weed infestation. The positive returns from minimum tillage are attributed to the absence of cultivation, low weed growth and less disturbance to the soil[13,14]. Thus, the production potential of medicinal plants can be judged by the effect of topographical aspect, tillage and tree canopy on growth parameters and yield of the species[15–17]. However understorey further influences the economic viability of medicinal plants when grown in association with trees[11,13,14].

A case study in Chir pine forests

Background

Chir pine (*Pinus roxburghii*) is one of the most important tree species in the subtropical regions of India. The forests of chir pine are found in Jammu and Kashmir, Himachal Pradesh, Uttarakhand, parts of Sikkim, West Bengal and Arunachal Pradesh. The total area under Chir pine forests has been estimated to be 890,000 ha, which occur between 450 and 2300 m altitude[12]. It has a wide adaptability and is less demanding on the soil and nutrients compared to other conifers[18]. This is the reason for its use in massive afforestation programmes in the country[19]. Nowadays plantations of chir pine are not preferred because of their susceptibility to five hazards, and they are being replaced by oak forests, although chir pine has often reduced the pressure on broadleaved trees like oak, which otherwise grow slowly[20,21]. Thus keeping in view the role of chir pine in massive afforestation programmes, and its ability to easily grow on dry and stony land having shallow soil depth, the present study reflects on the possibilities of growing MAPs and other economic species under degraded forests and monoculture plantations like chir pine, and utilizing the blank understorey of plantations for the commercial exploitation and conservation of medicinal plant resources, which otherwise remain infested with exotic weeds. Adoption of silvi-medicinal system would provide a green cover to the forest floor, thereby reducing the incidence of forest fires.

Scope of utilizing understorey of Chir pine forests

Various researchers have studied the understorey vegetation in Chir pine forests, which reflects the possibility of utilizing the understorey of these forests. For instance, Dutt and Gupta[22] reported the variations in herbage production under chir pine stands at four locations in the Solan Forest Division, Himachal Pradesh, India. They found that among different species, *Themeda anathera*, *Panicum maximum*, *Chrysopogon montanus* and *Pollinia* *argentea* were the major contributors to biomass production. Similarly, Joshi *et al.*[23] while working in Central Himalaya at Kumaun, recorded the vegetation cover of three sites (forested, partially forested and open grassland) in the *Quercus leucotrichophora–P. roxburghii* forest zone. They reported that a moderate level of disturbance in the partly deforested site led to an increase in herb species, but severe disturbances on the deforested site led to a drastic reduction in herb species. The life-form spectrum was phanerophytic, therophytic and hemigeophytic in forested, partly forested and deforested grazing lands respectively. The grass species observed were *Apluda mutica*, *Arthraxon lanceolatus*, *Arundinella nepalensis* (found in all three sites), *Cymbopogon distans*, *Cynodon dactylon*, *Dichanthium annulatum* and *Setaria glauca* (*S. pumila*). In general, *Digeteria decumbense* grass produced the highest fodder yield under pine; while *Thysonalenea maxima* and *Setaria kazungula* were also found to be promising when grown under pine[24]. However, the presence of MAPs, e.g. *Anaphalis busua*, *Buddleja asiatica*, *Ceterach officinarum*, *Desmodium triflorum*, *Evolvulus alsinoides*, *Holmskioldia sanguinea*, *Justicia diffusa*, *Sida rhombifolia*, *Sporobolus diander* and *Vicia sativa* has also been reported under Chir pine forests[25].

Methodology

The methodology involved growing MAPs in the Chir pine forests of the mid hills of North-West Himalaya at Dr Y.S.P. University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India. Seven MAPs, namely *Andrographis paniculata*, *Mucuna pruriens*, *Solanum khasianum*, *Spilanthes acmella*, *Withania somnifera*, *Cymbopogon nardus* and *Ocimum basilicum* were cultivated in Chir pine forests (Figure 1 *a–g*). These were grown on three topographical aspects, viz. Northern, North-Western and Western, by adopting three tillage depths, viz. minimum (0 cm), medium (up to 10 cm) and deep tillage (up to 15 cm), below and outside the tree canopy at 30 cm × 30 cm spacing.

The study was conducted in 20-year-old plantations of chir pine and the plots on different aspects were selected that were having equal density of trees (952 trees/ha). First, the pine needles were removed manually from the forest floor and then tillage practices were adopted to grow MAPs, before onset of the monsoon. The MAPs were raised in the nursery and transplanted to the field on the commencement of monsoon. Keeping in mind the excellent physio-chemical characteristics of soil and minimum input requirement of MAPs, no irrigation and fertilizer were applied to the plants.

Results

The yield of MAPs was recorded to observe the effect tree canopy, topographical aspect and tillage in degraded Chir pine forests. The yield of *Andrographis paniculata*, *Solanum khasianum*, *Spilanthes acmella*, *Withania somnifera*, *Cymbopogon nardus* and *Ocimum basilicum* outside the tree canopy was higher by 15%, 56%, 35%, 26%, 622% and 21% respectively, in comparison to below the tree canopy (Figure 2).

In addition, the yield of *Andrographis paniculata*, *Solanum khasianum*, *Spilanthes acmella*, *Withania somnifera*, *Cymbopogon nardus* and *Ocimum basilicum* was observed to be 1.38, 1.31, 0.76, 1.79, 1.17 and 0.77 times more respectively, on Western aspect compared to the Northern aspect (Table 1).

Similarly, the yield of *Andrographis paniculata*, *Solanum khasianum*, *Spilanthes acmella*, *Withania somnifera*, *Cymbopogon nardus* and *Ocimum basilicum* was recorded 38%, 31%, 0.76%, 79%, 17% and 0.95% more respectively in deep tillage than minimum tillage (Table 2). The yield of *Mucuna pruriens* did not differ much with variation in tree canopy, aspect and tillage in Chir pine forests.

Economic benefit

Positive economic returns (Rs/ha) were recorded from *Andrographis paniculata* (5003), *Mucuna pruriens* (12,208), *Solanum khasianum* (77,007) and *Spilanthes acmella* (5506), while negative returns (Rs/ha) were recorded from *Withania somnifera* (6079), *Cymbopogon nardus* (29,637) and *Ocimum basilicum* (5681) (Figure 3)[11]. This demonstrated that *Andrographis paniculata*, *Mucuna pruriens*, *Solanum khasianum* and *Spilanthes acmella* were more profitable in terms of economic returns and therefore have a great potential to improve productivity of degraded forests. The negative returns from *Cymbopogon nardus*, *Ocimum basilicum* and *Withania somnifera* when raised under Chir pine forests were due to non-suitability of *Withania somnifera* in shallow and compact hilly soil, and low light availability in case of *Cymbopogon nardus* and *Ocimum basilicum* under Chir pine forests. Sanwal *et al.*[26,27] have reported that negative returns from *Withania somnifera* when raised under *Pinus roxburghii* were due to non-suitability of the former in Chir pine forests. Perennial shrubs like *Ocimum gratissimum* were also present in the pine forests (Figure 1 *h*). Thus the introduction of MAPs under Chir pine forests is not only economically feasible with increased yield of such lands, but can also ensure regular supply of raw materials and *in situ* conservation[27]. Such practices will utilize lands under coniferous forest, viz. understorey of chir pine which had remained unexploited since decades, that will improve rural livelihood and economy of the state[28,29]. Utilizing the understorey of degraded forests like chir pine by producing native economic species under minimum tillage on appropriate aspects can possibly enhance the overall yield of such land without adversely affecting the soil physico-chemical properties, while conserving

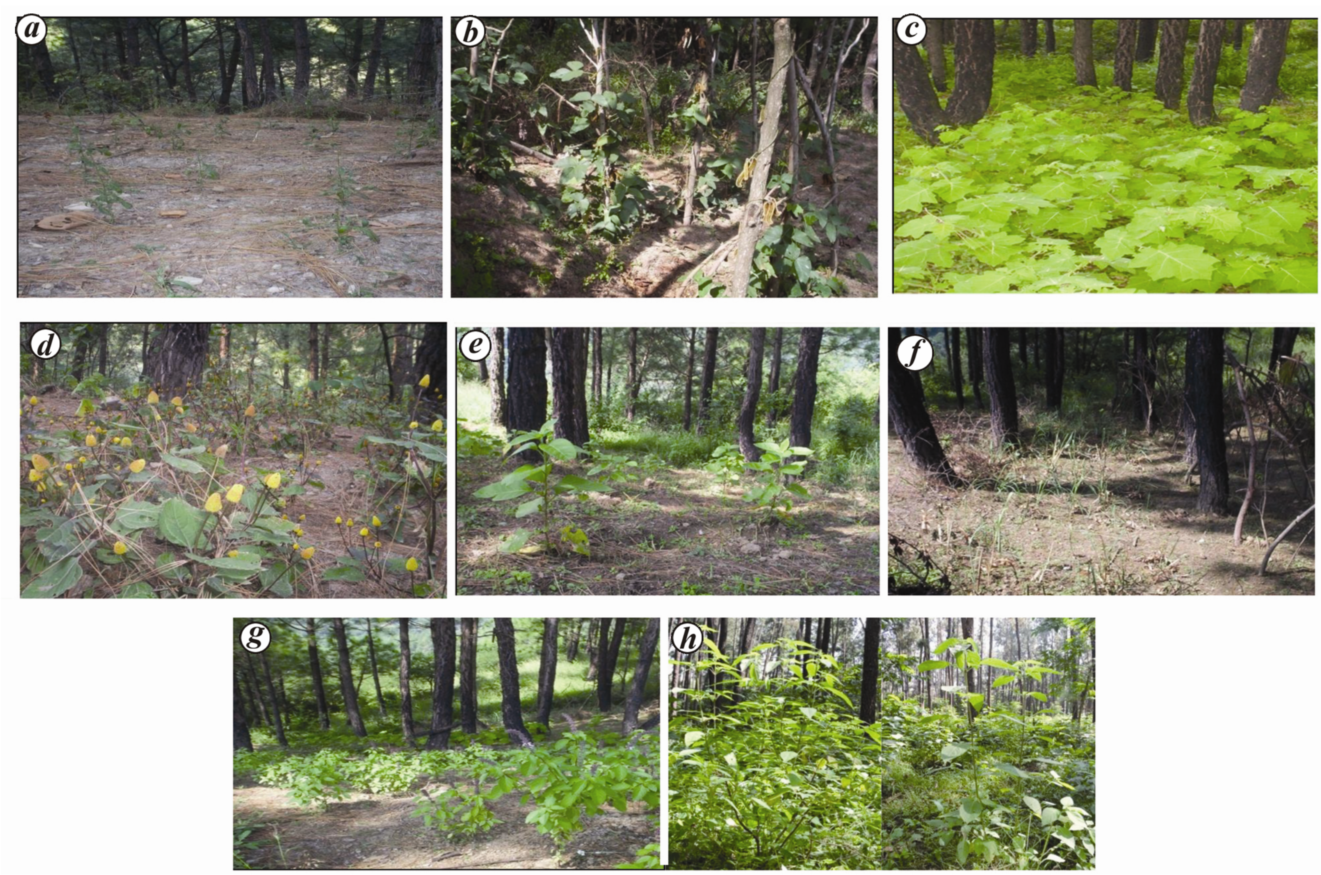

Figure 1. Growth of medicinal and aromatic plants in degraded Chir pine forests. ***a***, *Androgaraphis paiculata*; ***b***, *Mucuna pruriens*; ***c***, *Solanum khasianum*; ***d***, *Spilanthes sacmella*; ***e***, *Withania somnifera*; ***f***, *Cymbopogon nardus*; ***g***, *Ocimum basilicum*; ***h***, *Ocimum gratissimum*.

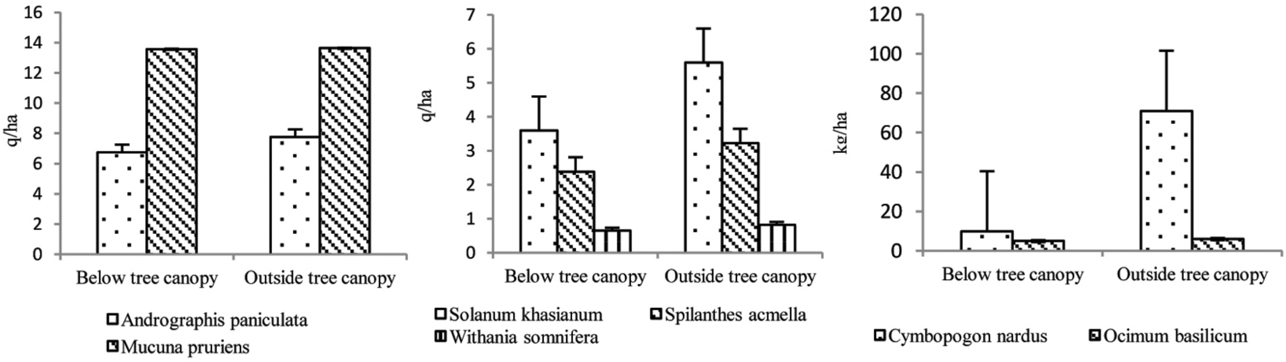

Figure 2. Effect of tree canopy on yield of medicinal and aromatic plants (MAPs) in Chir pine forest.

Table 1. Effect of tillage on yield of medicinal and aromatic plants (MAPs) in Chir pine forests

	Andrographis paniculata	*Mucuna pruriens*	*Solanum khasianum*	*Spilanthes acmella*	*Withania somnifera*	*Cymbopogon nardus*	*Ocimum basilicum*
Tillage	Shoot biomass (q/ha)	Seed weight (q/ha)	Berries weight (q/ha)	Shoot biomass (q/ha)	Root biomass (q/ha)	Oil (kg/ha)	Oil (kg/ha)
Minimum	6.28	13.52	4.00	3.21	0.52	37.35	6.02
Medium	6.38	13.53	4.10	3.13	0.53	38.64	5.95
Deep	6.66	13.57	4.30	3.03	0.62	39.62	5.74
Mean	7.26	13.60	4.63	2.84	0.73	40.40	5.31

Table 2. Effect of topographical aspects on yield of MAPs in Chir pine forests

	Andrographis paniculata	*Mucuna pruriens*	*Solanum khasianum*	*Spilanthes acmella*	*Withania somnifera*	*Cymbopogon nardus*	*Ocimum basilicum*
Topographical aspect	Shoot biomass (q/ha)	Seed weight (q/ha)	Berries weight (q/ha)	Shoot biomass (q/ha)	Root biomass (q/ha)	Oil (kg/ha)	Oil (kg/ha)
North-West	6.28	13.52	4.00	3.21	0.52	37.35	6.02
North	6.84	13.59	4.67	2.87	0.73	40.17	5.95
West	8.66	13.68	5.23	2.45	0.94	43.67	5.74
Mean	7.26	13.60	4.63	2.84	0.73	40.40	5.90

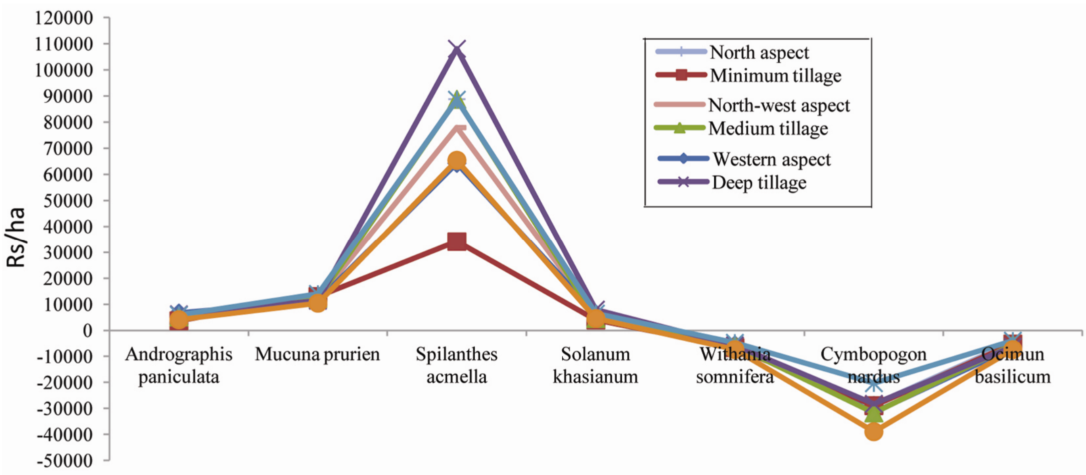

Figure 3. Economic returns (Rs/ha) from MAPs in Chir pine forests.

soil moisture and enriching the native biodiversity of the forests. This practice is also likely to reduce fire hazards which are reportedly causing harm to the forests since years, because such activity will not allow the flammable needles to accumulate in bulk in the understorey.

Monitoring conservation of medicinal plants

Once the understorey of degraded forest land is replenished by the green cover of native medicinal plants and their production is ready for sustainable harvest, monitoring has to be ensured while harvesting so that at least one-third of the produced native medicinal plants are left untouched so that they can be conserved and regenerate naturally for the future. Only the above-ground parts of medicinal plants need to be harvested to avoid soil erosion in case above ground part is economical. Deep ploughing or tillage must be avoided and the medicinal plant where root is the economical part should not be raised in the hilly terrain to avoid the soil erosion.

Conclusion

The present study provides an opportunity to sustainably produce and conserve the medicinal plant resources using management techniques, viz. optimizing aspect and tillage combinations under degraded forest of the country. It can also result in livelihood security of forest-dependent communities and revenue generation to the forest department besides *in situ* conservation of the medicinal plant resources and the reduced incidences of forest fire. Thus productivity enhancement by introducing suitable medicinal plants would not only reduce the pressure on the natural forests, where unscientific collection and exploitation of these herbs still continued till today, but will also conserve the medicinal plant resources in the wild.

Outcomes and recommendations

- Growing medicinal plants in the understorey of Chir pine forests is a viable option for enhancing diversification and earning additional income from these forests; it may be applicable to other forest type as well.
- Sustainable production and conservation of native medicinal plants can be made possible in the understorey of degraded forests, which are otherwise infested with the weeds.
- The practice will avoid continuous natural accumulation of dry leaves and litter as a result of sustainable production of MAPs which otherwise makes the forest floor prone to wild fire.

- Immediate returns after six months and revenue generation to Forest Department, besides providing seasonal employment to forest-dependent communities.
- Regular supply of herbs can lead to flourishing of pharmaceutical industries.
- If the understorey of degraded forests is utilized, it will provide a green cover and thereby help avoid fire hazards.
- The practice of raising native medicinal plants using sustainable techniques, like minimum tillage is recommended only in the understorey of degraded monocultural plantations to improve the soil, moisture and biodiversity status of the underutilized forest resources.

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