Medicinal plant cultivation and biosphere reserve management: A case study from the Nanda Devi Biosphere Reserve, Himalaya

R. K. Maikhuri*, S. Nautiyal*, K. S. Rao and K. G. Saxena†**

*G. B. Pant Institute of Himalayan Environment and Development, Garhwal Unit, P. Box 92, Srinagar (Garhwal) 246 174, India
**For correspondence: G. B. Pant Institute of Himalayan Environment and Development, Kosi-Katarmal, Almora 263 643, India
†School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110 067, India

Conservation-induced natural resource management options are of significance for effective management of biosphere reserves where people reserve conflicts are the prime attention of management plans. Nanda Devi Biosphere Reserve (NDBR) in Garhwal Himalaya is one such area where existing conflicts drew researchers' attention on management of natural resources. The cultivation of medicinal plants existing in this area has become a major activity with conservation-oriented land use changes. We describe here the agronomic practice and uses of eight medicinal and aromatic plants cultivated in the NDBR buffer zone villages of Garhwal Himalaya. The efficiency of resource use and economic returns indicate how such low-volume, high value crops which were suggested for this region have not only the potential for economic betterment of people of this area but also help the cause of conservation in this biosphere reserve.

THE geographical area included in Nanda Devi Biosphere Reserve (NDBR) is bestowed with rich natural resources, diverse ecological conditions and a long practice of traditional farming systems. Traditionally, the area produces plant-based raw materials used locally, regionally and very often supplied legally or illegally to different pharmaceuticals, aroma-chemicals-related industries. The reserve is also a repository of a variety of economically important medicinal plants and biologically significant animals. However, due to over exploitation in the past, abundance of many important species have been drastically reduced. Flora of the biosphere reserve area comprises of 341 species of trees, 552 species of herbs and shrubs and 18 species of grasses[1–6]. A total of about 97 species of plants have been reported to be used for a variety of purposes[6]. Six plant species are reported to be endangered and 12 are rare. The species such as *Aconitum heterophyllum*, *Podophyllum hexandrum*, *Dactylorrhiza hatagirea*, *Nardostachys grandiflora*, *Taxus buccata*, etc., are among the rare/endangered or threatened plant species that are of medicinal value.

Though various scientific and nongovernmental organizations have been advocating their cultivation and domestication in this region, unfortunately very few of them have reported about those medicinal plants which have already been brought under cultivation over the last 2–3 decades by the Bhotiya tribe of NDBR and adjoining area[7]. Despite achieving large-scale success in domestication/cultivation of a variety of medicinal plants, farmers of this region are still facing problems with marketing their produce. Therefore, emphasis needs to be given to establish cooperatives at village level to take marketing responsibilities of the produce.

While several studies describe the taxonomic features, chemical nature of the active constituents and ethnobotanical attributes of medicinal plants from different parts of the country[8–10], studies are lacking on domestication and cultivation of medicinal plants and their role in the local economy. This paper attempts to study (i) indigenous agronomic practices and uses, (ii) evaluation and comparison of yield of medicinal plants under cultivation and in wild, and (iii) output/input analysis (monetary) of cultivation and their role in the local economy. It also discusses the role of these practices to the conservation measures introduced in this protected area.

Nanda Devi Biosphere Reserve (NDBR), located in northern part of the Uttar Pradesh hills was established on 18 January, 1988 under the UNESCO's Man and Biosphere (MAB) Programme. It consists of a central core zone (624.62 km^2) surrounded by a buffer zone (1612.12 km^2). In 1992 it was declared as one of the world heritage sites by the world heritage committee of UNESCO. Legally the reserve includes areas of reserve forests, civil forests and panchayat forests and individual farm lands. From a geomorphological point of view, the buffer zone occupies the entire Rishi Ganga catchment (a tributary of Dauli Ganga) which is encircled by Himalayan peaks among which India's second-highest peak, Nanda Devi, flanks the northern part of the reserve. A total of 17 villages are situated in the buffer zone of NDBR, of which 10 villages fall in Garhwal (district Chamoli) and 7 villages in Kumaon (districts Pithoragarh and Almora). The present study was carried out in the 10 buffer zone villages belonging to Chamoli district of Garhwal Himalaya with a total population of 2253. The rural settlements are spread along an altitudinal zone of 2200–3600 m asl. The climatic year consists of three seasons: summer season (April–June), rainy season (June–September) and winter season (October–February). Average annual rainfall is 928.81 mm. About 47.3% of annual rainfall occurs over a short period of two months (July–August), featuring a strong monsoonic influence. Monthly maximum and minimum temperatures range between 24 to 14°C and 7.5 to 3°C, respec-

Table 1. Distribution, indigenous agronomic practices and uses of some medicinal plants cultivated in the buffer zone villages of NDBR

Species	Distribution	In brief agronomic practices	Uses
Allium humile Kunt	Found in nature between 2500 and 4000 m elevation in Central Himalayas and presently cultivated in the buffer zone villages of NDBR.	It is a perennial crop and requires dry cold climate. It is mostly propagated through root stock during monsoon season. Before planting root stock, the field is properly ploughed using bullock or digger (kudal). Large quantity of organic manure (about 30 t/ha) is added at the time of land preparation. Spacing between two root stocks is usually kept around 3–4 inches. During growing season it required 3–4 times weeding and is harvested thrice in a year (April, June and October). Harvesting is done using sickle and chopping done into small pieces which are sun dried. The total yield was estimated to be about 684 kg/ha/yr.	Used as a vegetable, spice and condiment. Soft leaves used as a vegetable and its regular use is considered to be very good for the patient suffering from jaundice, cold and cough. It is consumed in large scale by the locals and also exchanged/ bartered with other food items from the lower valleys.
A. stracheyi Baker	Found in nature between 2500 and 4000 m elevation in Central Himalayas and presently cultivated in the buffer zone villages of NDBR.	Agronomic practices are almost similar to *A. humile*. It is harvested once or twice in a year. The yield was estimated to be about 424 kg/ha/yr.	Uses similar to *A. humile*.
Angelica glauca Edgew	Found in nature between 2500 and 3500 m elevation in Central Himalayas and presently cultivated in the buffer zone villages of NDBR.	It requires cool and temperate climate and rich porous soil. Heavy inputs of manure, particularly sheep and goat dung and frequent weeding are essential for its better yield and growth. It is generally harvested once in three years, but sometimes farmers harvest it annually. Harvested roots are cut into small pieces and sun dried and stored for future use. The yield was estimated to be about 350 kg/ha/yr.	Root is mostly used as a spice and condiment and is considered a cardioactive stimulant, carminative, and diaphoretic. It is also used in dyspepsia and in constipation. The powered root is administered with warm water in stomach ailment of children and also checks vomiting. Leaves and stem of the plant are reported to be useful as stimulant, cordial and stomach troubles. Consumed locally and sold outside too.
Carum carvi Linn	Found in nature between 2500 and 3200 m elevation in Central Himalayas and presently cultivated in the buffer zone villages of NDBR.	It is cultivated as a summer crop between October and April and requires dry temperate climate. It thrives well in tilled soils rich in humus. It is mostly cultivated with other common crops, i.e. peas, garlic and require two time weeding. Seeds collected before ripening, dried, threshed out and stored. The yield was estimated to be about 500 kg/ha/yr.	Mostly used as a spice for culinary purposes. Besides, it is a carminative and also used in flatulent colic and as adjuvant for medicines. It is cultivated for local consumption and sold in the market.
Dactylorrhiza hatagirea (D. Don) Soo	Found in nature between 2500 and 4500 m elevation in Central Himalayas and presently cultivated in the buffer zone villages of NDBR.	Grow well in shady places and requires porous soil containing rich humus. Two time manuring and frequent weeding is considered to be good for better tuber growth. Propagated through seed or root cutting. Harvesting after 5 years of its cultivation is known to be good for higher yield but sometimes it is harvested after 2–3 years.	It is used as a farinaceous food, hervine tonic and aphrodisiac. Juice from its tuber is considered to be nutritious and useful in diarrhoea, dysentery and chronic fever. Used locally and also sold in the market.
Megacarpaea polyandra Benth	Found in nature between 2500 and 3800 m elevation in Central Himalayas and presently cultivated in the buffer zone villages of NDBR.	Same as *Angelica glauca*. Yield is estimated to be 255 kg/ha/yr.	Fresh and dried leaves used as a vegetable and decoction of the root is used to cure stomach pain and dysentery. Mostly consumed locally.
Pleurospermum angelicoides (DC.) CL.	Same as above.	Same as *Angelica glauca*. Yield is estimated to be 350 kg/ha/yr.	Decoction of the root is used to cure typhoid fever, stomach pain, body pain and dysentery. Also used as a spice and condiment.
Saussurea costus (Falc.) Lipsch	Found in nature between 2500 and 3500 m elevation in Central Himalayas and presently cultivated in the buffer zone villages of NDBR.	Same as *Angelica glauca*. Total yield is estimated to be 400 kg/ha/yr.	Decoction of the roots is used to cure stomach pain, tooth ache, worms and typhoid fever. Alcoholic extract of the root is found very useful in the treatment of bronchial asthma. Roots are also used as incense and insecticide to protect woollen cloths. Used locally and also sold in the market.

Figure 1. *Allium stracheyi* locally called pharan is being cultivated in Garpak village of NDBR buffer zone.

Figure 2. Luxuriant growth of *Carum carvi* in Tolma village of NDBR buffer zone.

tively. Parent material is crystalline rocks and includes garnetiferous mica schists, garnet mica, quartozone schists and mica quartzite. The soil in agricultural land is deep, black, loam to sandy loam and well to excessively drained.

The people inhabiting the buffer zone villages of NDBR located in the Chamoli part are Tolchhas', a Bhotiya community belonging to Indo-Mongoloid ethnic group. Except for the residents of Reni, Peng, Lata and Tolma villages, rest of the people have two permanent settlements: one in the valleys between 800 and 1500 m elevation and in the high elevation areas between 2400 and 3500 m. In 2000–3500 m elevation zone, rainfed cultivation on terraced slopes is the common agricultural practice. *Amaranthus* spp. (amaranth), *Phaseolus vulgaris* (kidney bean), *Fagophyrum* spp. (buckwheat), *Eleusine coracana* (finger millet), *Panicum miliaceum* (pearl millet), *Solanum tuberosum* (potato), *Triticum aestivum* (wheat) and a variety of pulses are common crops. A variety of medicinal plants, spices and condiments are also cultivated. Most of the crops and medicinal plants are potential cash crops.

Livestock comprises cows, bullocks, sheep, goat, horses and mules. All the households depend on forests for fuel, fodder, timber and leaf litter as organic manure. Wild resources of plant and animal origin make a significant contribution to the food security. Many plant species are used in traditional health care system. Some non-timber forest products not consumed domestically are also marketed for cash.

A survey of 300 households in NDBR buffer zone villages of Chamoli district was conducted to elucidate the local knowledge about uses of medicinal plants and the way these are domesticated/cultivated and marketed. The information was noted down during informal discussions with the people from each family. The acreage under medicinal/spice/condiments cultivation in the buffer zone villages was estimated by conducting a survey of all the villages. All the activities related to agronomic practices, trade and barter/exchange were monitored over a period of 3 years (1994–96) for more than 75 households in six villages. These households were selected because they were actively involved in cultivation and barter/exchange/marketing of medicinal plants. Existing marketing practices, exchange or barter systems, were evaluated. Village agents, wholesale dealers and terminal traders who formed the links in the marketing channel were consulted to determine the price spread. Monetary costs and benefits at each stage in the marketing were worked out.

Farm fields/kitchen gardens with different medicinal/spices/condiments were identified with replicate (three numbers for each) plots. Care was taken to ensure similar aspect and topographic conditions. Vegetation analysis of the fields was done when majority of medicinal plants attained maximum vegetative growth[11,12]. The economic yield per plant in a plot was determined as an average of 25 plants for each species. The economic yield per hectare in all cases was calculated on the basis of the yield from the entire plot. Similar observations were also made for these species in the wild (forests and alpine meadows) where they grow naturally. For output/input analyses, cost of material and labour for various activities was worked out on the basis of prevailing rates in the region.

Traditionally the medicinal plants were collected by *anwals* (animal herders) visiting the alpine grazing lands and by people from forests surrounding these villages. Though this process is still existing, cultivation of some of these plants because of their increased marketing potential was started in selected areas in Central Himalayas. Buffer zone villages of NDBR are prominent in this respect as it is only here that organized marketing

Table 2. Density and yield (kg/ha) of some medicinal, aromatic, spice and condiments cultivated in buffer zone villages of NDBR

Species	Vernacular name	Height (cm)		Density (no./ha)		Yield		% moisture in part used
		Cultivated	Wild	Cultivated	Wild	Cultivated	Wild	
Allium humile	Sedam*	40	25	220000	60000	684	160.0	91.6
A. strachevi	Jimbu*	25	18	190000	90000	424	99.5	90.2
Angelica glauca	Chippi	170	123	100000	245	985	5.1	83.0
Carum carvi	Kala jeera	85	60	70000	257	500	1.6	92.0
Dactylorrhiza hatagirea	Hathazari†	17	11	180000	42000	450	105.0	79.0
Megacarpaea polyandra	Barmao	112	80	120000	8500	850	60.5	89.8
Pleurospermum angelicoides	Choru	65	48	200000	283	1110	5.3	86.0
Saussurea costus	Kut	150	95	70000	215	1225	9.0	84.5

*Average density of plantlets was found to be 19–22 in wild. Under cultivation it was 56–64.
†Usually harvested after three years of planting.

Table 3. Medicinal plant acreage and projected production in the buffer zone villages of NDBR

Species	% families cultivating the species	Gross acreage (Ha)	Projected production (kg)	Monetary value of the produce (Rs)	Output:input ratio of resources under cultivation
Allium humile	76.0	5.44	3720	204600.00	13.0
A. stracheyi	76.0	2.70	1144	62690.00	9.0
Angelica glauca	11.0	0.96	945	23640.00	8.0
Carum carvi	20.0	0.80	400	32000.00	25.0
Dactylorrhiza hatagirea	0.5	0.40	64	14400.00	12.5
Megacarpaea polyandra	2.0	0.20	170	2550.00	6.0
Pleurospermum angelicoides	2.0	0.20	222	5550.00	9.0
Saussurea costus	18.0	0.84	1029	25725.00	9.0

of the produce is being attempted. Brief description, indigenous agronomic practices and uses of eight medicinal plants cultivated in buffer zone villages of NDBR are given in Table 1. All the eight species are naturally-occurring in the region between 2500 and 4000 m elevation and have dwindled in numbers due to past exploitation. Because of their low-density distribution in nature, they are no longer economically viable for exploitation and ecologically unviable due to poor regeneration. However, the increased density of these plants under cultivation indicates the extent of intensification that is possible under management system (Table 2). Agronomic yields are high under cultivation on per unit basis and also on individual basis except for *Allium* spp. and *Megacarpaea polyandra*, which showed higher agronomic yield per individual in nature than under cultivation.

Though cultivation of medicinal and aromatic plants was practised by all families, the total acreage and acreage under cultivation for various species varied greatly. Only *Allium* spp. were found to be commonly cultivated by 76% of families cultivating these species and 67% of total land was under cultivation of medicinal plants under these species with *A. humile* occupying 2/3 area of this total land (Table 3). Due to specialized management skill requirements, only 0.5% of families have been reported to cultivate *Dactylorrhiza hatagirea*. However the total acreage under cultivation of this species is higher than that of *Pleurospermum angelicoides* and *M. polyandra* which were being cultivated by least number of families (2%). Owing to its acreage alone, *Allium* spp. contributes 50% of total volume of produce and 55% of monetary value of the produce. The per hectare

Figure 3. *Angelica glauca* under cultivation in NDBR buffer zone villages.

Table 4. Quantity (kg) and monetary value (Rs) of the produce consumed, exchanged/bartered and sold in the market in the buffer zone villages of NDBR

Species	Quantity			Monetary value		
	Consumed	Exchanged	Sold	Consumed	Exchanged	Sold
Allium humile	86	2232	1402	4730	122760	77110
A. stracheyi	25	686	433	1375	37730	23815
Angelica glauca	170	472	303	4250	11800	7575
Carum carvi	8	140	252	640	11200	20160
Dactylorrhiza hatagirea	1.7	9.8	52.5	382	2205	11812
Megacarpaea polyandra	105	65	–	1575	975	–
Pleurospermum angelicoides	222	–	–	5550	–	–
Saussurea costus	123	341	565	3075	8525	14125

yield per year and its monetary value was high for *A. humile* which showed both highest acreage under cultivation and number of families cultivating it. The total monetary value of all the produce was estimated to be about Rs 3,71,155/yr for the buffer zone villages of NDBR in Chamoli district alone. The output/input analyses using monetary values indicated *Caram carvi* provided highest returns and *M. polyandra* provided least returns.

Though organized marketing is starting, majority of the produce is still used to barter for food items. Of the total produce (7694 kg/yr), least (550.5 kg/yr) is used for self consumption and maximum (4038 kg/yr) is used for barter and the rest is being marketed directly (Table 4). While *A. glauca* and *S. costus* are consumed locally in large quantities in comparison to others, *A. humile* is used both for barter and direct marketing in large quantity than other species.

Nanda Devi Biosphere Reserve region is one of the most biologically diverse areas of the Central Himalayas. Though the area lies in a high-altitude region, dramatic change in elevation has resulted in the existence of a number of unique vegetation types distributed over a variety of topographical and climatic zones. The situation has acted both as a bridge, facilitating the influx of many taxa, and as a barrier, promoting endemism in the area. The reserve is a repository of a large number of medicinal plants and animals having economic value. This makes NDBR an area of immense importance. However, due to excessive exploitation, populations of a variety of plant and animal species have shrunk in size and these species are now rare, endangered and threatened. Examples of plant taxa are *Aconitum heterophyllum, Podophyllum hexandrum, Dactylorhiza hatagirea, Nardostachys grandiflora, Taxus buccata*, etc. Although no formal studies have been made, it is certain that genetic diversity has been reduced in rare faunal species like the snow leopard (*Panthera uncia*), brown bear (*Ursus arctosisabellinus*), musk deer (*Moschus chrysogaster*), monal pheasant (*Lophophorus impejanus*), Himalayan snowcock (*Tetraogallus himalayensis*), snow patridge (*Lerwa lerwa*), etc. NDBR also has a great potential for tourism which would help alleviate the economic conditions of the tribal population of this region. Furthermore, the control of the village resources (through village Panchayat forests) in most parts of the buffer zone is indeed strong. There is a high degree of people's participation in the community resource management for biodiversity conservation and economic development. Here are some of the largest and best-maintained community forests which are the result of natural resources conservation on account of 'Chipko movement' which originated from the buffer zone village, i.e. Reni.

Dependence on natural resources for subsistence requirements existed in this region since time immemorial. However, exploiting these resources for cash is a recent phenomenon. This might have resulted from increase in demand for these resources by bioindustries which started extending their product base and marketing opportunities using the traditional knowledge-based healing systems. The conservation priorities in NDBR area required changes in natural resource accessibility regimes and reduced the area of accessibility. This resulted in depletion of scarcely available resources at faster rates from areas of easy accessibility. Medicinal and aromatic plants were among them. Though the ecodevelopment component of biosphere management action plan attempted to provide alternate economic opportunities to mitigate the hardships caused by conservation-oriented land use changes, none of them was accepted by indigent people[3].

Medicinal plant cultivation has existed for a long time in this region, however, due to increased economic gains this practice has become more intensive. Though intensive management tends to bring improvement in yield both per plant and per unit area, the prominent crops, *Allium* spp. and *M. polyandra*, showed that this was not true as shown in the present study. Domestication of *Dactylorrhiza hatagirea*, a rare/endangered species of the region, indicates that this might be helpful in reducing pressures in the wild for this species. According to

Figure 4. *Saussurea costus* cultivation in Garpak village in NDBR buffer zone.

the local people, although the endangered species of this region could be cultivated, because of lack of sufficient market infrastructure for all species, they could not do it at present.

Animal husbandry was the major activity of the people for cash income in the region before conservation-oriented land use changes occurred. Wool and woollen products were used both for exchange or cash from the sale to meet family requirements. With altered land use in biosphere area, the existing animal husbandry activities had to be curtailed and thus reduced the cash income. People immediately shifted to medicinal plant exploitation though it was banned since 1982 itself from the region. The prolonged conflicts and competition for economic opportunities encouraged the local people to increase the cultivation of *Allium* spp. which they were doing traditionally and bring more species under cultivation. *Allium* spp. still occupies more than 67% of land put to medicinal plant cultivation in the area.

Among the medicinal plants currently under cultivation, *Carum carvi* showed highest returns per unit of inputs. Even from the financial point of view, this is a high value crop and increase in its acreage will increase the total return to the people of the region. For common agricultural crop cultivation, the returns per unit of input is far below the medicinal plant cultivation in this region. Thus increasing the acreage for cultivation of medicinal plants would increase the efficiency of the resource use and also financial returns. The larger difference in price of the produce from production site to terminal market indicates the scope for increased returns to producers through organized marketing of the produce. As most of the produce are high-value, low-volume crops advocated for the region, providing infrastructure facilities and incentives for such activities is felt needed in management action plans to make people more friendly with biosphere reserve management plans[13].

The existence of market forces for medicinal plants, though, was not mentioned in earlier publications from the region, the amount of this material used for barter/exchange for domestic requirements indicates this might be existing for a long time. Our enquiries revealed, though this existed since very long time, it only increased with reduction of woollen products, which were main products of exchange/barter. Obviously this occurred after the area was brought under administered conservation programme through National Park declaration and then Biosphere Reserve. The quantity of consumption indicates that domestic consumption could still sustain through extraction from wild itself, as could be seen for the species that were not under cultivation at present such as *Aconitum* spp., *Podophyllum* spp., *Rheum emodi*, *Picrorrhiza kurrooa*, *Nardostachys grandiflora*, *Taxus buccata*, etc. However, increasing demands for these species makes it necessary to start their cultivation to meet the growing requirements. The areas such as buffer zone villages of NDBR are highly prospective for this as these species naturally occur here.

From biosphere management aspect, restoring large tracts of degraded lands adjacent to settlements was identified as a major action component to reduce people's dependence on forests otherwise needed for wildlife habitation. However the action plan concentrated only on major produce such as fuel, fodder and minor timer rather than the economic dependence of people on nonwood products from forests. Management attention given by local communities towards the lands under their control made policy planners to emphasize for peoples' participation for conservation programme implementation in government-controlled areas[13]. Medicinal plant cultivation on restored lands could be encouraged under management action plans to increase peoples' participation and improve economic status of local inhabitants. Such a rehabilitation approach could integrate the objectives of stabilization of degraded slopes, improvement in rural economy and reduction of exploitation pressure from natural forests in

Himalaya[14–17]. Conservation education and awareness programme implementation in the management action plans need to be given proper attention for reducing conflicts[16,18]. If residents of buffer zone villages of NDBR could begin large-scale cultivation of low-volume, high-value crops such as medicinal and aromatic plants to derive greater economic benefits along with improved efficiency of resource use, this might lead to reduced dependence on forests for nonwood products and reduce illegal poaching activity and thus help achieve the objective of conservation of biological resources and better management of Nanda Devi Biosphere Reserve.

1. Anonymous, *Programme of Man and Biosphere*, Department of Environment, 1987, p. 126.
2. Balodi, B., *The Crops of Engineers Scientific and Ecological Expedition, Nanda Devi – 1993*, mimeographed.
3. Hajra, P. K. and Jain, S. K., *A Contribution to the Botany of Nanda Devi National Park*, B. S. I., Howrah, 1983, p. 38.
4. Khacher, L. K., *Him. J.*, 1976, **19**, 191–209.
5. Khacher, L. K., *J. Bombay Nat. Hist. Soc.*, 1977, **75**, 868–887.
6. Samant, S. S., *The Crops of Engineers, Scientific and Ecological Expedition, Nanda Devi – 1993*, mimeographed.
7. Khoshoo, T. N., *G. B. Pant Memorial Lecture*, G. B. Pant Institute of Himalayan Environment and Development, Kosi–Katarmal, Almora, 1992.
8. Jain, S. K., *Dictionary of Indian Folk Medicine and Ethnobotany*, Deep Publications, Delhi, 1991.
9. Kirtikar, K. R., Basu, B. D. and An, I. C. S., *Indian Medicinal Plants*, Bishen Singh Mahendra Pal Singh, Dehra Dun, 1984.
10. Rastogi, R. P. and Mehrotra, B. N., *Compendium of Indian Medicinal Plants*, CDRI, Lucknow and Information Directorate, CSIR, New Delhi, 1991.
11. Kershaw, K. A., *Quantitative and Dynamic Plant Ecology*, Edward Arnold, London, 1973, p. 308.
12. Misra, R., *Ecology Workbook*, Oxford and IBH Publishing Co., New Delhi, 1968, p. 244.
13. Maikhuri, R. K., Nautiyal, S., Rao, K. S., Saxena, K. G. and Semwal, R. L., Proceedings of the Regional Workshop on Community Based Conservation (ed. Kothari, A.), IIPA, New Delhi, 1996, in press.
14. Dobriyal, R. M., Singh, G. S., Rao, K. S. and Saxena, K. G., *J. Herbs Spices Med. Plants*, 1997, in press.
15. Ives, J. D. and Massareli, B., *The Himalayan Dilemma: Reconciling Development and Conservation*, Routledge, New York, 1989.
16. Ramakrishnan, P. S., Purohit, A. N., Saxena, K. G. and Rao, K. S., *Sustainable Development and Himalayan Ecology*, Indian National Science Academy, New Delhi, 1994.
17. Ramakrishnan, P. S., Purohit, A. N., Saxena, K. G., Rao, K. S. and Maikhuri, R. K., *Conservation and Management of Biological Resources in Himalaya* (ed. Ramakrishnan, P. S. *et al.*), Oxford and IBH Publication, 1996, pp. 585–595.
18. Chandrakanth, M. G. and Romm, *J.*, *Nat. Res. J.*, 1991, **31**, 741–756.

ACKNOWLEDGEMENTS. We thank the Director, G. B. Pant Institute of Himalayan Environment and Development, Kosi–Katarmal, Almora for facilities. Financial support from Mac Arthur Foundation of USA through UNESCO office in Delhi for the work is acknowledged. We also thank the anonymous reviewer for his valuable suggestions and help in revising the manuscript. Views expressed are of authors only and not necessarily of the affiliated organizations.

Received 19 August 1997; revised accepted 12 November 1997.

Change in wheat productivity with time in long-term experiment

P. R. Vaishnav, H. M. Bhatt and S. K. Dixit

Department of Agricultural Statistics, Gujarat Agricultural University, Anand 388 110, India

The use of moving average values reduced the seasonal/irregular fluctuations in the data effectively and gave better fit as compared to that of original set of data. For wheat crop, various degrees of polynomials with different bases ($X^{0.5}$, $1/X^{0.5}$ and X) explained the trend in yield due to various treatments. Majority of the fitted curves showed initial moderate increase, followed by a downward trend in the productivity till a later stage. The initial expected productivity ranged from 1525 (control) to 2544 kg/ha (NsPsKs). The productivity at last point of time ranged from 406 (control) to 2908 kg/ha (NsPsKs). In the medium black soil of Junagadh, under intensive cropping system, NsPsKs treatment was found better as compared to rest of the treatments in wheat crop.

LONG-term field experiments yield information on direct, residual and cumulative effects of fertilizer application. Such experiments also help in studying the changes in the productivity of the soil over time. Though the average performance of the treatment under study over time remains an important measure of productivity, the change over time in either crop or environmental traits or both is the more critical parameter. Obviously, an increasing rather than a decreasing productivity trend is an important feature of a desirable technology.

More recently, the long-term fertilizer experiments are conducted on a crop sequence containing two to three crops instead of single crop. The analysis of data is usually undertaken for the individual crop in the sequence, as no procedure of analysis is available for combining different crops in the sequence[1]. As treatment effects are likely to be different on different crops, it is difficult to decide weight of one crop equivalent to unit weight of other crops. Usual split plot analysis does not provide information about the trend of various treatments over a period of time. In all the long-term experiments, time is a quantitative factor, hence, a common practice is to partition time into components associated with orthogonal polynomials[2]. In most of the cases, a simple linear trend either positive or negative