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MANAGED CROP POLLINATION

The Missing Dimension of Mountain Agricultural Productivity

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Preface

Applied research on sustainable mountain agricultural development issues has been a principal undertaking of the Mountain Farming Systems' Programme of ICIMOD since 1988. The project on 'Strategies for Sustainable Mountain Agricultural Development' not only focussed on the analysis of farmers' strategies and public interventions, but also on research on the latest technological innovations to increase and maintain farm productivity supported by programme activities. Farming with comparative advantages and harnessing and conserving the local resource base, as far as possible, are the key strategies of technology identification and promotion at ICIMOD.

Most of us know that beekeeping is one of the integral components of the small-scale, off-farm activities of mountain farmers. The products from beekeeping provide cash income and nutritive food items to the household, besides pollinating crops. Thus, the conventional notion of beekeeping is that it is 'primarily to produce honey and other hive products with crop pollination as a secondary activity'. The latter benefit is not assured but assumed under the conventional beekeeping approach.

However, with the ongoing transformation of mountain agriculture from subsistence systems to commercial agriculture, new challenges to improving and maintaining productivity are emerging. Among these challenges are crop failures due to lack of pollination. Hence, the need for managed crop pollination will increase in future all across the HKH Region. Isolated incidences of this have been recorded by ICIMOD from a number of mountain areas. This calls for a more intensive focus on the issue from the perspectives of policy, research, development, and extension. Improving institutional capabilities and developing human resources are key areas needing attention.

This paper analyses the need for managed crop pollination in the light of the findings of experimental research carried out so far by ICIMOD and in the light of the current information on crop pollination. The paper tries to present an alternative perception to beekeeping and that is: 'to promote beekeeping primarily for crop pollination with honey and other beehive products as by-products.' The new approach combines the two benefits well but institutional reorientation in the context of policies, research, and extension might be necessary.

Experimental research demonstrates the scope managed crop pollination provides to improve productivity. The need to manage the pollination of cash crops in mountain areas is indicated by research into agricultural development processes. Constraints to and opportunities for promoting managed crop pollination in the HKH are analysed in this paper.

Abstract

The ongoing transformation of mountain agriculture from subsistence systems to diversified agriculture is bringing forth new research and development challenges to maintaining productivity. One among these several challenges is crop failure caused by the lack of pollination. Hence the necessity for managed crop pollination is going to increase in the coming years throughout the Hindu Kush-Himalayan Region. Isolated evidence of this problem has been recorded by ICIMOD through research in several pocket areas. This Discussion Paper analyses the need for managed crop pollination in light of the findings of experimental research carried out by ICIMOD over the last few years and in light of other information available on crop pollination. The paper has tried to present an alternative perspective to the significance of beekeeping. It discusses pollination as a natural ecological process which is vital for the production of fruits and seeds. The scope for and experiences of managing honeybees and other pollinating insects for the pollination of different crops have been discussed. In this respect, the paper highlights the importance of honeybees and the economic value of bee pollination. It has also compared the foraging behaviour of the Himalayan honeybee, *Apis cerana,* and the European honeybee, *Apis mellifera,* in relation to their efficiency in pollinatiing different fruit crops and their suitability for crop pollination in different agro-ecozones. The role of managed crop pollination in food security, biodiversity conservation, and in overall agricultural development processes shows that, in the very near future, a greater need will be felt for managing pollination of cash crops in mountain areas. The paper sums up by outlining the possible constraints to and opportunities for promoting managed crop pollination in the Hindu Kush-Himalayan Region.

Contents

Productivity Management Options for Mountain Farmers

For mountain farmers, the most desired goal in crop farming is to get the maximum possible crop yields under constrained input conditions and ecological settings. For this purpose, farmers also try to improve the quality of the produce, particularly fruits and seeds produced for the market. It is particularly important to get a premium price for the produce when farmers are engaged in cash crop farming. In addition, using better quality seeds always helps to ensure a healthier crop harvest.

There are two well-known methods for improving crop productivity. The first method is the use of improved agronomic/culturable methods. The culturable/agronomic methods include plant husbandry techniques such as the use of good quality seeds and practices to improve yields, e.g., providing good irrigation, organic manure, and inorganic fertilizers and pesticides. The second crop productivity method includes the use of biotechnological techniques, e.g., manipulating the rate of photosynthesis and incorporating biological nitrogen-fixing techniques, genetic engineering, and so on. While these conventional techniques ensure a healthy growth of crop plants, these work only up to a limit. At some stage, crop productivity might even become stagnant or decline with additional inputs, since the known agronomic potentials of the crop will have been harnessed.

The third and less known method of increasing crop productivity is through managing pollination of crops using friendly insects, which, in the process of searching for food, perform a useful service to farmers. Pollination is an ecological process based on the principle of mutual interactions or relationships between crop plants and insect species.

The impact of cross-pollination on crop productivity definitely depends on the extent to which the crop can be pollinated. Therefore, if crop pollination is managed so that each flower is pollinated, a new dimension will be added to increase harvests and improve quality. This unique ecological option requires no inputs apart from the management of friendly insects, e.g., honeybees.

Traditionally, honeybees are used in various ways by mountain farmers; primarily for honey and other hive products that are used as foods and medicines, some of which bring in cash. Bees also play a role in maintaining the productivity of various agricultural and horticultural crops through crop pollination. The significance of this aspect of beekeeping to agricultural productivity has not been fully appreciated. With increasing emphasis on commercialisation of mountain agriculture, mostly through cross-pollinated crops, i.e., fruit or vegetable crops (Tables 1 and 2), crop pollination should become a priority area for R&D, if the productivity of mountain agriculture is to be maintained.

The Mountain Farming Systems' Programme at ICIMOD has been working on various aspects of honeybees and crop pollination in the HKH Region for the last

Table 1: Vegetable Production in the Hindu Kush-Himalayan Region

Country	Area ('000 ha)	Production ('000 tons)	Estimated Annual Seed Requirement (tons)
Indian Himalayas[1]	318.1	1354.4	1200
Nepal[2]	140	741.6	500
Pakistan[3]	282.9	1418.8	2312.5
Bhutan[4]	1.8	-	10
China (Himalayan-Hengduan Region)[5]	14.5	26.3	60

Source: [1]Singh 1993; [2]Gurung 1993; [3]Alam 1993; [4]Wangchuk 1993; [5]Du et al. 1993

Table 2: Fruit Production in the Hindu Kush-Himalayan Region

Country	Apples		Other Temperate Fruits	
	Area ('000 ha)	Production (000 tonnes)	Area (000 ha)	Production ('000 tonnes)
Indian Himalayas[1]	203	1052	530	1595
Nepal[2]	5	50	46.2	293
Bhutan[3]	1.5	87.7	.13	-
Pakistan (NWFP)[4]	17.4	166	29.8	252
China (Himalayan-Hengduan Mountain Region)[5]	-	24.2	1.4	21.5

Source: [1]Singh 1993; [2]Gurung 1993; [3]Wangchuk 1993; [4]Alam 1993; [5]Du et al. 1993

six years with the objective of improving the knowledge in and increasing institutional focus on these topics. This work has resulted in unique information about both Himalayan honeybees (*Apis cerana*) and crop pollination in mountain areas. The purpose of this discussion paper is to share this knowledge and create more awareness on this lesser known dimension in increasing crop productivity. It reviews the role of honeybees in increasing crop yields and improving the quality of various crops. This paper analyses the need for bee pollination in the light of the agricultural transformation that is taking place in the HKH Region and which is documented in the research carried out by the Mountain Farming Systems' Programme.

Furthermore, the paper discusses issues related to the comparative benefits of native and European bees, an outcome of the ICIMOD project on 'The Promotion and Development of Beekeeping through the Preservation of the Indigenous Asian Honeybee, *Apis cerana*'. The final section outlines challenges for promoting managed crop pollination. Promoting complementarity between the indigenous Asian honeybee species, *A. cerana*, and the European species, *Apis mellifera*, as pollinators is recommended for effective use of both species. While use of *A. cerana* could be promoted in the high hills, *A. mellifera*, which has already been introduced in the low hill areas, could be used for both crop pollination and honey production.

Pollination as a Factor Controlling Crop Productivity

The Natural Ecological Process

Pollination of crops is essential for crop productivity and without it crop yields can be difficult to maintain. The process involves proper floral pollination of crops leading to fertilization to form future fruits and seeds. Pollination ensures the transfer of pollen grains from the anther to the stigma of (i) same flower (self-pollination) or (ii) another flower of the same plant species (cross-pollination). Pollination is a prerequisite for fertilization which is the union of the male nucleus of pollen grain with the female nucleus of the ovule. Fertilization is essential for seed and fruit development. Pollination is, therefore, the most crucial factor and process in the production of seeds and fruits; if there is no pollination, no seeds and fruits will be produced by the crops.

The process is vital for completing the life cycle of plants and ensuring better crop yields; whether for grain crops, seeds, or fruits. It is based on the ecological principle of species' interrelationship and interaction, known as 'protocooperation', between natural pollinating agents, largely insect species, and the crop plants.

Most crops are actually self-sterile and require cross-pollination to produce seeds (Free 1993; McGregor 1976). Moreover, it is not only self-sterile varieties that benefit from cross-pollination, but self-fertile varieties also produce more and better quality seeds if they are cross-pollinated (Free 1993). While other agronomic practices, such as use of manure, fertilizers, pesticides, and irrigation are important, without cross-pollination of the flowers by natural insect pollinators, such as different species of wild bees, flies, beetles and moths, and so on, crops remain underexploited.

The Need for Managed Crop Pollination

Inherent problems and limitations in the natural pollination system are more evident in mountain areas. The first problem is that, although the natural pollinating agents, largely insect species, play an important role in the pollination of various summer crops grown in the mountain and hill climates, these pollinating agents cannot be useful to mountain farmers for pollinating the crops that flower during winter and spring; for instance, vegetables such as cauliflowers, cabbages, radishes, broad-leaved mustard, and fruit crops such as apples, peaches, plums, and pears. This is because these pollinating agents are absent during this period and also, since these insects cannot be domesticated, it is not possible to use them in managing crop pollination.

The second problem is the declining population of natural insect pollinators; and among the reasons for this could be the decline in habitat, with the accompanying decrease in food supplies, and negative impacts of modern agricultural interventions, e.g., use of chemical fertilizers and pesticides which are toxic for many species (Deodikar and Suryanarayana 1977; Verma 1990; Verma and Partap 1993). One indicator of the decline in natural insect pollinators is decreasing crop yields, despite necessary farm inputs. For example, in the North West Frontier Province (NWFP), despite agronomic inputs, there has been a decline in fruit yields over the last few years (personal communication, AKRSP). Declining trends in apple production in Himachal Pradesh are now recognised to be due to lack of pollinating agents.

The third problem is related to the increase in crop areas requiring pollination by a limited population of natural pollinators. So far, natural pollinating agents have been sufficient for local subsistence farming systems and also for limited areas under introduced crop species. However, with an increase in cash crop farming and larger areas of crops that require cross-pollination, a shortage of pollinators will ensue. The adverse impacts of these changed cropping systems on productivity can well be imagined.

Any one of the above three reasons has the potential to hinder pollination. The threat also emphasises the need for more research and development into crop pollination. Unfortunately, there are few institutions, especially in mountain areas, devoted to research on crop pollination and productivity. Policy-makers, planners, researchers, and extension workers should be made aware of the importance of promoting management of crop pollination in strategies for maintaining agricultural production.

Scope for Managing Crop Pollinators

The Natural Agents

Nature has provided natural pollinating agents that perform crop pollination as part of their search for food from flowering plants. These agents include hundreds of species of insect pollinators, e.g., flies, beetles, moths, butterflies, and bees. The most important among these are the different species of bees such as bumble bees, solitary bees, and honeybees. In a few exceptional cases, insects other than bees are essential crop pollinators, e.g., the two insect species, *Theobroma cacao* and *Elaeis guineensis,* that pollinate the oil palm. But these insects lack body hairs and the necessary behavioural characteristics, and probably only a few of them actually transfer pollen (Free 1993). Furthermore, unlike bees, which forage consistently to obtain sufficient food for their young, most other insects forage to satisfy their own immediate needs. Hence, it is assumed that they only perform a supplementary role in pollination. Probably, the most important supplementary pollinators are the various *Diptera*, including those belonging to the genera *Eristalis, Syrphus, Platycheirus, Calliphora, Bibio,* and *Bombylus*.

To be an efficient pollinator, an insect must visit several flowers of the same species in succession, moving frequently from one flower to another, carrying plenty of pollen on its body and brushing against the stigmas of flowers for transference (Free 1993). Some species of *Diptera* carry as much pollen on their bodies as bees, but they do not visit the flowers consistently.

Experience in Management of Pollinators

If emphasis needs to be placed on neglected aspects of crop productivity, e.g., through managed crop pollination, it will be necessary to rear insect pollinators on a large scale for use in crop pollination. These pollinating insects would be using an unharnessed niche, i.e., the pollen and nectar of flowers. While foraging for nectar and pollen, these insects will perform valuable pollination services.

In the developed countries of the West, attention is given to the management of pollinating insects on a commercial scale, even to those other than honeybees, especially bumble bees and solitary bees. These insects are being reared and used for the pollination of alfalfa and crops such as tomatoes and potatoes that are not pollinated as effectively by honeybees. For example, there are 10-15 companies located in western Europe, Israel, New Zealand, the USA, and Canada which are rearing bumble bees. In 1992, these companies sold 300,000 colonies valued between US$30-60 million (Doorn 1993). Two companies in the Netherlands rear bumble bees on a large scale and market these to farmers as crop pollinating agents. Some companies in Japan are reportedly importing bumble bees and other insects on a commercial scale for use with tomato and potato pollination.

In the developing countries, although both the need and the potential exist, the practice of managing crop pollination using honeybees only is limited. Development and use of other insects in this part of the world will take a long time. In the HKH Region, managed crop pollination using honeybees or other agents is even less prevalent, despite the fact that the productivity of cross-pollinated cash crops is declining and that there is a rich beekeeping tradition; although this is primarily for honey.

The Scope for Managed Crop Pollination

Economic Effectiveness of Managed Crop Pollination

To determine the economic effectiveness of bee pollination within the limits of an individual farm or an administrative region, experimental data on the increase in yield for soil types on a certain farm or the average for an entire region are necessary. To carry out such work, it is necessary to know the average increase in yield for different soil types in a district, province, or the whole country. It is appropriate to use the average data on the increase in yields after bee pollination over a number of years. These data should be expressed in percentages of total yield per hectare rather than in natural values. The basis for determining the economic effectiveness of managed crop pollination is provided by data on the increase in yield. Unfortunately, these data are not yet available for the HKH Region, but data are available from other parts of the world for most of the crops responsive to bee pollination.

The promotion of managed crop pollination has been a common practice in the State owned and community farms in the former USSR for the past three decades and more. Therefore, the method and the subject matter are exemplified here by studies carried out in the former USSR (Saldatov 1976). The average indices for increase in yield, which are expressed in percentages of the total yield per hectare, were: fruit crops-35, lucerne-65, red clover-82, sunflower-35, buckwheat-39, mustard-56, rape-30, coriander-35, cucurbits-25, cotton-28, cucumber-11, grapes-29, and linseed-19. This increase in productivity is converted into net gains of production countrywide, using the total area under crops pollinated by bees and the total production of grains, seeds, or fruits and calculating the additional production.

The expenses incurred in establishing apiaries are set off by the economic benefits accruing from the pollination of crops, depending on the crops pollinated. These expenses include the work of the apiarists and a certain degree of depreciation and mortality, nominal expenses for feeding the bees, and so on. The annual expenditure for managing beehives for pollination has been estimated at about 30 per cent of the total direct and indirect expenses, indicating a high degree of economic efficiency for this process (Soldatov 1976).

The expense of rearing bees for crop pollination, in spite of substantial returns, unfortunately, is not included in the cost of production of pollinated crops. This harms not only the bee industry but also crop husbandry. The extremely profitable cottage industry in bees is considered to be a part of the agricultural economy operating on minor gains in income.

Further, the economic effectiveness of managed crop pollination with bees is characterised by the cost evaluation of the additional yield and expenditure and also by the impact on the cost of producing the main products.

Primacy of Honeybees for Crop Pollination

Pollination of crops by honeybees is one of the most practical and most promising methods of increasing crop production. Honeybees have flower fidelity/constancy, have a potential for long working hours, and can be managed in sufficient numbers where and when required. Bees collect pollen and nectar to supply to the next generation, whereas other insects collect for their individual needs only. Bees, therefore, make more flower visits. Their long tongues, coats of long collecting hairs, and the ability to warm themselves and to work in cool weather make them generally more efficient pollinators than most other insects.

The practical use of honeybees for this purpose began in 1895 in the U.S. when honeybees were used as pollinators to avoid crop failure in Virginia (Waite 1895) and used for apple pollination in other states of the USA (Benton 1896). Therefore, over the past few decades, researchers have included other agricultural and horticultural crops within the scope of honeybee pollination (Sakharov 1958; Radchenko 1966; Kozin 1976; McGregor 1976; Manzoor et al. 1978; Adlakha and Dhaliwal 1979; Manzoor and Muhammed 1980; Crane and Walker 1984; Kevan 1984; Deshmukh et al. 1985; Dulta and Verma 1987; Verma 1990).

HKH Experiences of Managed Crop Pollination

Realising the valuable role honeybees play in increasing yield and improving the quality, beekeeping is now being promoted as an essential component in the pollination of fruit crops and in vegetable seed production in the HKH Region. Farmers in Himachal Pradesh now use honeybees to pollinate apples and other fruits. The government of Himachal Pradesh has created an institutional infrastructure for rearing and managing bee colonies, and it rents these to farmers at a nominal cost of one US$ per colony per season as an encouragement to farmers. Some of the farmers have started bee-rearing on a large scale for rental purposes also. The use of honeybees for crop pollination is also increasing in the Chinese Himalayas (ICIMOD 1996a; 1996b; 1996c).

The results of ICIMOD's research on vegetable and fruit crop pollination reconfirm the usefulness of bee pollination and its role in increasing crop productivity and improving the quality of fruits and seeds (Partap and Verma 1992; 1994; Verma and Partap 1993; 1994). Table 3 sums up the findings of experiments carried out by ICIMOD staff on popular vegetable cash crops in the Kathmandu Valley.

Table 3: Honeybee (*A.cerana*) Pollination Impacts on Vegetable Seed Productivity in the Hills

Crop	Increase in Pod Setting (%)	Increase in Seed Setting (%)	Increase in Seed Weight (%)
Cabbage	28	35	40
Cauliflower	24	34	37
Radish	23	24	34
Indian Mustard	11	14	17
Lettuce	12	21	9

Source: Verma and Partap 1993

Box 1: Economic Value of Bee Pollination: Some Experiences

Many economic estimates of the value of managed honeybee pollination to crop production in different countries have been worked out. For example, the value of bee pollination in crop production is estimated at US$ 20 billion per year in the USA (USDA-ARS 1991); Canadian Dollars 1,200 million in Canada (Winston and Scott 1984); and about 3,000 million dollars in the EEC (Williams 1992). Cadoret (1992) worked out bee pollination inputs to crop productivity for 20 countries in the Mediterranean region to be almost US$5.2 billion annually; of this, US$3.2 billion is estimated to go to agricultural production in the developing countries of the region.

The value of bee pollination for New Zealand's economy has been calculated at about US$ 2,253 million per year (Matheson and Schrader 1987), almost 113 times more than the bee products sold by New Zealand's beekeepers. This also includes the value of nitrogen-fixing on New Zealand's pastures by honeybee pollinated legumes.

In the former USSR, researchers have shown that, given the constancy of other conditions, bee pollination gives an additional yield of buckwheat on an average of 3q/h. For the whole of eastern Siberia, this increase would amount to 90,000 quintals of additional grain.

In China, the economic values of honeybee pollination on four major crops, viz., rape, cotton, tea, and sunflower, have been estimated to be more than 6 billion *yuan* (US$ 0.7 billion), which is six to seven times more than the direct income from bee products (Chen 1993). Though attempts have not been made to estimate the value of bee pollination in the countries of the Hindu Kush-Himalayan Region, it is undoubtedly considerable.

Scientific evidence confirms that bee pollination also improves the yield and quality of other vegetable crops grown by mountain farmers such as asparagus, carrots, onions, turnips, and so on (Deodikar and Suryanarayana 1977). When bees are used for the pollination of popular fruit crops in mountain areas, it improves the fruit set, reduces fruit drop, and improves fruit quality in apples, almonds, apricots, cherries, citrus, guavas, litchis, peaches, pears, plums, persimmons, and strawberries (McGregor 1976; Ahmad 1987; Dulta and Verma 1987; Free 1993). Experimental evidence also indicates the positive effect of bee pollination on productivity of forage crops (Deodikar and Suryanarayana 1977); of cardamom, a high-value spice crop from Sikkim and Ilam (Chandran et al. 1983); of buckwheat (Suryanarayana and Deodikar 1977); and of the main oil seed crops such as mustard, sesame, safflower, niger, and sunflower (Rao et al. 1984).

Simplicity of Crop Pollination Technology

After years of research and experimentation, scientists have developed farmer-friendly techniques of honeybee pollination for a number of agricultural and horticultural crops (Kozin 1976; Free 1993; Verma 1990). For example, a simple and very effective method of pollinating vegetable crops with honeybees is by introducing large bee colonies (each colony consisting of at least 7-8 frames covered with bees) in the field when flowering is about five to ten per cent. The colonies are kept in the field until the flowering period ends. Large, strong colonies are better pollinators because large colonies usually have more older bees as foragers. The number of colonies required depends upon the number of flowers and the strength of the bee colonies. In general, two colonies of *A. mellifera* per hectare of crops in bloom are recommended. Keeping in mind the small size and shorter flight range of *A. cerana,* three to four colonies per hectare are recommended (Verma 1990).

Table 4. Increase in Crop Productivity due to Bee Pollination

Increase in Fruit Production (x times)		Increase in Seed Production (x times)	
Production (x times)			
Apples	x24	Large Cardamom	x10
Lemons	x15	Mustard	x1.4 - 1.6
Litchis	x2	Turnips	x1.2
Peaches	x2	Sesame	x1.3
Pears	x14	Sunflower	x1.5
Persimmons	x1.2	Onions	x1.7
Plums	x6		

Source: Eva Crane 1991

Eva Crane (1991) has summed up the experimental findings and experiences of crop pollination with honeybees. Table 4 illustrates the key findings of her work.

Factors Controlling the Quality of Pollination

The quality of pollination is presumably determined by the strength of the colonies participating in the pollination of crops. Years of research and experiment attest the effectiveness of managed crop pollination (Baga 1976). Research also indicates that the greatest efficiency can be achieved by bringing the requisite number of healthy and strong beehives to crop areas in order to ensure complete pollination, or saturation. The value of achieving saturation is that crop yields are 15-20 times greater (Baga 1976). Experiences from pilot experiments and practical farming have shown that the best results are obtained by using large bee colonies, each of which contains 50,000-70,000 worker bees (*A. mellifera*). A small bee colony performs four to five times less pollination work than a large one.

Actual guidelines for the saturated pollination process have to be worked out by researchers for each area and region. For example, in the Ukraine, scientists have set the following conditions; in spring, keeping the bees in multi-framed hives, a strong bee colony may occupy 10 or more frames, a moderate colony seven to nine frames and a weak colony fewer than six frames (Baga 1976). During summer, this number is reduced to four, three, and two, respectively. As an incentive to good management on the part of apiarists and satisfactory pollination of agricultural crops, Russian scientists practised a system of Crop Certification Ratings of Bee Pollination. This certificate indicated the number of bee colonies in the field for the pollination of a particular crop and specified the colony strength. The impact on quality and quantity of crop produce was estimated from these two factors.

The arrangement of colonies in crop fields is important in order to ensure uniform distribution of foraging bees and, thus, uniform pollination of crops. Honeybees primarily visit those sources of pollen or nectar that are within a 300-500m radius from the apiary. At a distance of over 500m, the number of foragers decreases, and thus the pollination activity diminishes significantly. Therefore, for effective pollination of crops it has been recommended to distribute the bee colonies inside the field instead of placing them into groups.

Box 2: Role of Insect Pollinators on Yield and Quality of Apple Crops

Most of the commercial varieties of apples give good yields only after cross-pollination. Cross-pollination is carried out by insects, because the role of wind in cross-pollination of apple bloom is negligible; this is because of the sticky nature of apple pollen. The results of experiments carried out in the Shimla hills of Himachal Pradesh show that bee pollination provides a major contribution to improving fruit set in apple orchards. In the absence of insect pollination, particularly in self incompatible varieties of apples such as the Royal and the Red Delicious (the two most popular types with farmers from a commercial point of view), fruit set does not take place. Although some varieties, such as Golden Delicious, may require bee pollination to contain the percentage of fruit drop, experiments also ascertained that bee pollination significantly improves the quality of apples in terms of weight and size.

______Dulta and Verma 1987

The findings of experimental research carried out in the Kullu and Shimla hills of Himachal Pradesh also suggest that in apple orchards with 20 per cent pollinizer*, placing bee colonies in groups of four, each group separated by 50m, gives maximum fruit set. In apple orchards having only three per cent pollinizer, better fruit set is possible by keeping three colonies in a group than by distributing them singly. Under the ideal pollinizer ratio of 30 per cent, farmers can achieve a better fruit set of 30-44 per cent by keeping four bee colonies per hectare.

______Gupta et al. 1993

* Refers to the plant supplying the pollen

Efficiency and Complementarity between A. cerana and A. mellifera

There are at present five species of honeybees found in the Hindu Kush-Himalayan Region. Among these, *A. cerana, A. dorsata, A. florea,* and *A. laboriosa* are native to the region, but only *A. cerana* are kept in hives in order to collect honey. The European hive bee, *A. mellifera,* was introduced into this region over the last few decades because it produces more honey. It is already popular with lowland and hill farmers in countries of the Hindu Kush-Himalayan Region. Also, the institutional support for beekeeping is mostly directed to the promotion of *A. mellifera* for honey production only.

So far, attempts to keep other species of honeybees in hives have not succeeded. These species make their single comb nests in the open air on branches of trees or on rock overhangs on vertical cliff faces, and local communities collect honey through traditional honey hunting methods.

The Asian hive bee, *A. cerana,* and the European hive bee, *A. mellifera,* are comparable in many ways, and both have their advantages under different mountain farming conditions. Under the low and mid-hill subtropical conditions of the HKH region, it is observed that *A. mellifera* performs better than *A. cerana* in terms of honey production and has prolific queens. It is also observed to have less swarming and absconding tendencies. However, scientists have warned against the trend of replacing *A. cerana* with *A. mellifera* which has led to the near extinction of several races of *A. cerana* from these areas of the HKH (Verma 1994). This is an unwelcome process of erosion of genetic diversity.

In addition, there are reports about the comparative advantages *A. cerana* has over *A. mellifera* in the cooler mountain climates of the HKH Region, in terms of both honey production and pollination purposes. In fact, this point can be used as a basis of the strategy for saving *A. cerana* through proper use.

While searching for complementarity between the two species, one finds that they differ in some of their behavioural aspects, particularly in terms of foraging behaviour and habitat preference. From the point of view of crop pollination, these are the key attributes of honeybees; these characteristics differ between the two species vis a vis efficiency in pollinating crops in different agroecological zones. Whereas *A. mellifera* is successful at lower altitudes and in the plains, *A. cerana* has a broader ecological coverage and is therefore used by farmers from the plains to the high mountains. Its more productive strains are, however, found in high mountain areas, e.g., Jumla in Nepal, Himachal Pradesh and Kashmir in India (ICIMOD 1994a; 1994b), and Yunnan in China (Bangyu and Tan 1996).

Studies on the comparative effectiveness of *A. cerana* and *A. mellifera* in pollinating different vegetable and fruit crops in the hills/mountains have shown that *A. cerana* is a better pollinator of vegetable and fruit crops flowering during early spring (Partap and Verma 1992; 1994; Verma and Partap 1993; 1994). Compared to *A. mellifera, A. cerana* begins foraging earlier in the morning and ceases late in the evening. *A. cerana,* thus, continues pollinating for a longer period of time on a particular day. It also visits and pollinates more flowers per minute than *A. mellifera* (Table 5).

Table 5. Comparative foraging behaviour of *A. cerana* and *A. mellifera*. (Values are mean±SE)

Parameter	Peaches		Plums		Pears	
	cerana	*mellifera*	*cerana*	*mellifera*	*cerana*	*mellifera*
Commencement of foraging activity (time of day)	0701 ± 3	0734 ± 3	0710 ± 2	0740±3	0655 ± 5	0720 ± 4
Cessation of foraging activity (time of day)	1806 ± 2	1745±5	1801±5	1740±3	1803±5	1803±4
Total duration of foraging activity (hrs)	11.1 ± 0.8	10.11±0.9	10.5±0.2	10.00±0.3	11.35±0.8	10.43±0.9
Peak hours of foraging activity (time of day)	1100 - 1400	1100-1300	1100-1400	1000-1300	1100-1400	1000-1300
Duration of foraging trip	20.2 ± 2.7	25.3±3.1	21.4±1.3	24.9±2.5	19.8±1.5	22.6±1.8
Number of flowers visited per foraging trip	187.1 ± 3.5	205.1±2.8	168.3±3.8	273.5±3.7	229.2±8.8	282±5.2
Number of flowers visited per min.	TW 9.74 ± 1.2 SW 4.1 ± 0.9	8.9±1.5 3.4±1.0	8.8±1.1	15.0±2.2	13.6±1.3	12.5±0.9
Time spent (s) per flower	TW 4.8 ± 1.6 SW 12.6 ± 1.3	5.4±1.5 16.4±1.7	6.8±2.9	4.6±1.8	3.4±0.9	3.2±0.7
Ratio of top workers (TW) versus side workers(SW)	9:1	2:8	10:0	9:1	10:0	9:1
Weight of pollen loads	14.5 ± 2.2	15.4±2.4	13.1±1.7	17.1±2.0	13.5±1.8	24.8±3.4
Number of bees/1,000 flowers at a distance of 0-250m 250-500m	11.8 ± 2.4 5.6 ± 1.9	11.0±1.6 5.5±1.3	9.4±3.5 5.5±1.1	7.1±1.2 4.2±1.8	8.5±1.0 5.3±0.8	6.3±1.0 3.1±1.5

Source: Partap 1996

In the Hindu Kush-Himalayan Region, both species are being used for crop pollination. *A. mellifera* has been found to be more suitable for beekeeping in the low hill areas. Beekeepers produce more honey from these bee species and the farmers benefit from their pollination services. However, under the agroecological conditions prevailing in mountain areas, beekeeping with *A. mellifera* is not viable. This species is very susceptible to cold, and this results in high mortality during winter. Therefore, as a management strategy, the colonies need to be transferred to the low hill/plains during winter, i.e., from November to March. In the

Gilgit area of the North West Frontier Province of Pakistan, where *A. mellifera* has been introduced on a large-scale, reports are that it is not effective in pollinating fruit crops that flower during late winter or early spring.

Contribution of Managed Crop Pollination to Food Security and Biodiversity Conservation

Managed crop pollination can play a significant role in alleviating poverty, ensuring food security, and maintaining biodiversity. Agriculture is the mainstay of over 80 per cent of the rural population in the countries of the Hindu Kush-Himalayan Region. However, as many as 93 per cent of the farmers in the hill and mountain areas of the region are marginal or small land-owning families cultivating up to one to two hectares of land (Partap 1995).

Information collected by ICIMOD through various studies indicates that the agricultural land resources in most mountain areas are not only marginal in productivity but are also deteriorating further, as indicated by declining soil fertility and crop productivity. In many areas this is leading to food shortages of varying degrees among mountain families. These food shortages are further setting a chain reaction into a process of poverty-resource degradation-scarcity-poverty (Jodha and Shrestha 1993). This pessimistic scenario means that efforts should be made to explore all possible ways to increase the productivity and carrying capacity of these farming systems. This, however, cannot be done by emphasising cultivation of grain crops alone.

If mountain farmers are going to compete favourably in the modern world, instead of being swallowed up by it, they must be given options and alternatives that are not already captured by competition. Cash crop farming – horticultural and off-season vegetables - is one comparative advantage that can be exploited by mountain farmers. This also is one of the few promising options available for promoting food security; at least in some mountain areas.

Isolated experiences of cash crop farming in the Hindu Kush-Himalayan Region demonstrate that mountains can never have a comparative advantage in producing adequate foodgrains (Partap 1995). Thus, mountain farmers today have an increasing inclination to grow vegetables and fruits which bring in substantial incomes. The production of both seasonal and off-season vegetables is increasing in different parts of the Hindu Kush-Himalayan Region, where many small farmers are engaged in vegetable production both for local markets and for export purposes (Table 1). A variety of temperate and subtropical fruits, such as apples, peaches, pears, plums, almonds, apricots, grapes, and cherries is also being grown (Table 2). Logically, this should increase the need for managed crop pollination in these areas. Equally interesting is the adoption of apiculture as an enterprise by many people, and it is particularly popular now in the North West Frontier Province of Pakistan. In these areas, mobile apiaries are employed for honey collection, and these are ready-made resources for managed crop pollination of mutual benefit to different interest groups. There are few linkages between cash

Box 3: Comparative Advantages of *Apis Cerana* over *Apis Mellifera* for Crop Pollination in a Mountain Environment

- *A. cerana* begins its foraging activities early in the morning when temperatures are low. According to reports, the foraging activities of *A. cerana* take place at temperatures 5-7°C lower than those known to initiate *A. mellifera* foraging activities. This is especially significant for mountain/hill agricultural productivity.
- The peak foraging activities of *A. cerana* are observed at temperatures 5-6°C lower than those of *A. mellifera*. Thus, *A. cerana* could be used for the pollination of crops flowering in late winter or early spring in hill/mountain areas.
- The average duration of the daily foraging activities of *A. cerana* is longer than *A. mellifera*. This is because of the early initiation and late cessation of foraging activities in the former species. *A. cerana* may, thus, ensure adequate pollination of crops in less time, particularly during adverse weather conditions, e.g., during the frosty spring season when honeybee activities are severely curtailed.
- *A. cerana* can forage at temperatures as low as 7°C. Such cold hardiness in this native bee species offers comparative advantages to mountain farmers keeping bees for pollination purposes, especially for crops such as apples, peaches, plums, and cherries which flower during late winter or early spring.
- The flight range of *A. cerana* is half that of *A. mellifera*. This is of particular interest, especially when pollination of small plots of specific crops is the case. An *A. cerana* hive, when placed in the vicinity of a specific crop, restricts itself to pollinating that crop only and does not wander off or escape to other areas.
- Beekeeping with *A. cerana* requires lower maintenance costs than *A. mellifera*; the latter requires expensive technology which marginal farmers in developing countries of the Himalayan region cannot afford. Moreover, colonies of *A. cerana* require a lesser degree of chemical treatment to control epidemics.
- Many vegetables, oil seeds, fruits, and other crops have evolved together with *A. cerana*. It is likely that these plants have developed symbiotic relationships with this bee species, and they are, thus, indispensable to each other. Exotic *A. mellifera* may disturb this coexistence and inefficiently pollinate these native crops reducing their reproductive success.

Source: Verma and Partap 1993

crop farmers and entrepreneurs with mobile bee colonies in these areas of Pakistan, and this could be because of the lack of awareness about the benefits of managed crop pollination.

Cash crops assume great importance in helping farmers emerge from the poverty trap (Koirala 1992; Sharma 1995, Sharma and Sharma 1996; Yanhua et al. 1992). In addition, the economics of these pocket areas indicates that there is food security and reasonable economic well-being (Partap 1995). The concerns of farmers engaged in cash crop farming are with maximising yields and improving the quality of their produce, whether of fruits, seeds, or other plant parts. This broadened concept of food security, which focusses on efforts to increase access to food rather than growing grain crops, is already being promoted, both by farmers and by the governments, as the basis for transforming subsistence mountain agriculture. The trends in agricultural development in the HKH Region clearly indicate that, in the coming decades, farmers in the region will move more and more towards cash crop farming in order to harness the comparative advantages of the mountain environment (Partap 1996).

Encouraged by global forces of liberalisation, a broader concept of food security, and new knowledge about the comparative advantages of mountain farming, national and local governments and supporting institutions are already working towards changing the focus of agricultural development in mountain areas. National planning, e.g., the Agricultural Perspective Plan of Nepal; provincial planning, such as Agenda 21 for sustainable agriculture in Tibet; or Agricultural Development Plans in Himachal Pradesh; and the local government strategies seen in Ningnan and Miyi Counties, Sichuan, China are clearly supportive of promoting commercialisation of mountain farming (APROSC and John Mellor Associates 1995; XAR 1996; Yanhua et al.1995). This development process is creating a need to integrate agricultural development planning and managed crop pollination.

The positive implications of crop pollination in cash crop farming and thus to food security and poverty alleviation are very clear. Farmers will have to opt for ways of ensuring sustained yields from cash crops. Among the different factors affecting the yield and quality of new cash crops, pollination has the most critical role. As stated earlier, many commercial varieties of fruit and vegetable crops grown in mountain areas are self-sterile and thus require cross-pollination of their flowers for a healthy harvest. Cross-pollination of flowers by honeybees and other natural insect pollinators is therefore one of the effective processes for maintaining yield and quality in fruits, seeds, and grains.

Exploiting this option for augmenting crop productivity is essential for improving the food security situation. Also, with natural crop pollination at risk, farmers may no longer be able to afford risking crop production because of the uncertain services of natural insect pollinators. It will, therefore, become necessary to promote the use of honeybees and domesticated insects, with which mountain farmers are quite familiar, for managed crop pollination in order to avert the crisis in mountain agriculture.

Helping Conserve Himalayan Honeybees

The HKH Region is home to several native species of honeybees. Among these *A. cerana* is a popular honeybee with mountain farming communities, and it is managed traditionally for the production of honey. In recent decades, the European honeybee, *A. mellifera*, was introduced into the HKH Region because it is a better honey producer under modern management conditions. The result has been that *A. mellifera* has replaced *A. cerana* in several areas of the HKH Region. Studies carried out by ICIMOD and others have shown that today there are only a few areas where *A. cerana* can be found, e.g., in Nepal, the Indian Himalayas, and Yunnan, China (ICIMOD 1994a; 1994b; Bangyu and Tan 1996). In Pakistan, where *A. mellifera* was promoted much more vigorously in the Northern Areas, the last strains of *A. cerana* survive with a few hundred villagers in Kalash Valley in Chitral (personal communication, AKRSP).

Experts argue that the coming decade may be crucial in the context of saving the Himalayan honeybee species, *A. cerana,* from extinction (Verma 1994). Already several good races might have been lost, even before they could be documented. Evidence is now available indicating that *A. mellifera* has already displaced the native, *A. cerana,* species in many low hill areas of the Hindu Kush-Himalayan Region, due to its allopatric nature.

However, managed crop pollination in mountain areas provides the hope of saving *A. cerana* from extinction. Research carried out at ICIMOD (Verma and Partap 1993; 1994; Partap and Verma 1992; 1994) and elsewhere indicates that there is a useful role for both species in crop pollination.

The knowledge and information available indicate that it is possible to promote crop pollination strategies in which both *A. cerana* and *A. mellifera* can be made to play complementary roles. Both species are good pollinators in different agro-ecological zones. The races of *A. mellifera* which have been introduced into the HKH do not survive in the cold winter and spring temperatures of these mountain areas. *A. mellifera* has to migrate to low hill areas with warmer temperature regimes. Therefore, as described earlier, it is less useful for pollination of major cash crops in mountain areas. On the other hand, research on the genetic diversity and productivity of *A. cerana* carried out under a special ICIMOD programme (Verma 1994) showed that a subspecies of *A. cerana,* i.e., *A. cerana cerana,* occurs in the high mountain areas of the HKH Region. It is larger in size, darker in colour, and equivalent to *A. mellifera* in terms of honey production. Since this subspecies of *A. cerana* is well adapted to the cold climatic conditions of high mountain areas, it would be highly suitable for the pollination of spring flowering crops and honey production in most mountain agro-ecosystems.

Since *A. mellifera* is good for the warmer agroclimatic conditions of low and mid-hill areas, it should be restricted to these areas only. *A. cerana,* particularly the subspecies occurring at higher altitudes (notably Jumla in Nepal, Kashmir and Himachal Pradesh in India, and Yunan in China), is good for colder, agroclimatic mountain regimes. This information gives a vital clue to the complementary roles that can be played by both species in crop pollination and in producing useful by-products, i.e, honey and other beehive products. Thus, natural zonation of bee pollination areas to be served by *A. cerana* and *A. mellifera* can also become the basis of conservation strategies for saving *A. cerana.* Like crops, conservation of honeybees is also related to farmers' choices. Therefore, conservation through promoting use of *A. cerana* for pollination is certainly a good option.

As mentioned earlier, the Asian honeybee, *A. cerana,* is in crisis, and, therefore, our dependence on this honeybee species might clearly exacerbate the pollination crisis. Unless this species is saved, it will limit the scope for managed crop pollination in native areas where farmers practise traditional beekeeping; in this event new pollinators will have to be identified, tested, managed, and promoted. The cost of the latter would indeed be high.

Lastly, wider use of managed crop pollination is possible with the key assumption that insecticide application in crop husbandry will be replaced by other alternatives. It is important to save bees, the crop pollinators, from the adverse effects of chemicals. While it may not discourage use of chemical fertilizers in crop management, integrated pest management (IPM), the key component of organic farming, receives more focus. Therefore, in promoting managed crop pollination, organic farming approaches should be integrated into the whole process.

The Challenges to the Promotion of Managed Crop Pollination

The emerging need for managed crop pollination in HKH agriculture is very timely, in the sense that stray cases of crop failure through lack of sufficient pollination are being noticed by farmers and there are increasing reports of threatened extinction of the basic resource for the solution, the *A. cerana* honeybee. Combining conservation of bee species with development option seems the logical way forward.

Knowledge Gap and Research Needs

While raising awareness about the need for managed crop pollination with the information and knowledge available is one thing, a big challenge confronts researchers. Even before policy-makers and development agencies begin to make use of this option on a wider scale in mountain agriculture, the gaps in our knowledge need to be closed. Several questions still remain unanswered in this respect; e.g., when mountain farmers record (or will record) declines or total failures in crop yields due to lack of pollination (confirmed by scientific studies), it may be due to the reasons given below.

- The crops were not pollinated because natural insect pollinators were killed by pesticides (a common accusation).
- Full crop pollination failed in a particular mountain valley because the area under crops far exceeded the number of plants for which natural populations of insect pollinators, including honeybees, were able to offer pollination services.
- The fruit set was observed to be hopelessly poor, despite good blossoms of peaches, cherries, apples, and other crops in cold mountain areas where people might be keeping *A. mellifera*.

These three scenarios generate the following questions for research: are there enough populations of insect pollinators in mountain areas to help pollination of new, much larger cash crop areas? Or is the pollination failure because of the seasonality dimension? It could be that there might be enough insects, including

A. mellifera, but these are available in the summer season when other traditional crops might be flowering. Most of the introduced fruit crops in the HKH Region bloom in the spring when it is too cold for many insects to offer pollination services. Further, in the light of the above two points, it will not be safe to assume that all crop failures are because of insecticides. Also, research has not been carried out on other insect pollinators. Initiatives on commercial production of pollinators in the HKH Region, except for the use of honeybees in a few cases, have not been undertaken so far in any country, by any institution. These are some of the knowledge gaps. Scientists working in this field could list many more that have to be addressed before the concept of managed crop pollination is put to practical use.

Institutional Strengthening Needs: Research and Extension

Managed crop pollination is a relatively new area, and there are only a few institutions in the HKH Region that have explicit mandates and manpower capabilities with ongoing large-scale research and extension in this area. Most apicultural institutions focus on the honey production aspect and look on honeybee research and management mainly from that angle (Table 6). Similarly, development agencies promote beekeeping as a cottage industry to increase family incomes through the sale of honey. It was, in fact, assumed that nature would take care of the pollination of crops and, under normal circumstances, this was so. Therefore, there is a need to strengthen the research capabilities in order to underline applied research in key areas of managed crop pollination in mountain agriculture. Issues such as the extinction of *A. cerana* and its conservation needs have not been adequately addressed so far by the institutions in the HKH Region.

Mainstreaming Isolated Efforts through Policy Support

As reported, there have been a few instances of farmers using honeybees for pollination of crops in Himachal Pradesh in India and Yunnan in China. In these two provinces, government institutions are providing extension services to popularise the approach. These are only isolated cases, limited to a few areas. On the other hand, great efforts have been made to develop apiculture as a microenterprise/cottage industry. The result of these initiatives is that, today, mountain areas in Pakistan, China, and also in northwestern India have successful examples of apicultural enterprises, primarily for honey. However, the main missing link between the two is the explicit primary focus of apiculture for crop pollination. This dimension is missing in policy and planning approaches and, therefore, receives less research and dissemination attention, even though reasonable knowledge and information might exist, at least in some countries. Efforts are therefore needed to create conditions for inclusion of managed crop pollination in the priority areas of sustainable agricultural development and to emphasise the integration of managed crop pollination as a key component of agricultural development policies.

Table 6. The Research and Development Focus of Beekeeping Institutions in the HKH Countries

Country	Institution	R&D Focus
Afghanistan	National Beekeeping Programme	*A. mellifera* for honey production
Bangladesh	Tropical Bee Research and Training Institute, Naogaon	*A. mellifera* for honey production
China	Eastern Bee Research Institute, Yunnan Agricultural University, Kunming	*A. cerana* for honey and pollination research
India	• University of Horticulture and Forestry, Himachal Pradesh	Mainly *Apis mellifera* for honey and pollination research
	• H.P. Department of Horticulture	Mainly *A. mellifera* for honey and pollination research
	• Uttar Pradesh Department of Horticulture	Mainly *A. mellifera* for honey and pollination
	• Central Bee Research and Training Institute, KVIC, Pune	Mainly *A. mellifera* for honey and pollination
Myanmar	Beekeeping Department, Ministry of Livestock Breeding and Fisheries	*A. mellifera* for honey production
Nepal	Bee Development Programme, Department of Agriculture	Mainly *A. cerana* for honey as a cottage industry
Pakistan	Pakistan Agricultural Research Council (PARC), Islamabad	*A. mellifera* for honey production

Source: Compiled by the Authors

In the intensive farming zone where mostly cash crops are grown, such as Himachal Pradesh, the Swat area in Pakistan, and several counties in southwestern China, the bee industry is not fully used to meet the interests of crop husbandry and the cultivators incur great losses through the poor exploitation of bees for the pollination of flowers. Although experimental evidence proved that, with correct organisation of crop pollination by bees, the income from bee pollination of crops can increase 10-fold.

Under the conventional system of apiculture for honey production, not much profit is made from pollination. This is because, currently, apiarists receive little financial incentive from the pollination service they may be rendering. Their efforts are considered to be rewarded by the honey and wax produced by the bees. This way apiarists who may be helping pollinate crops are in fact encouraged to disrupt organisational measures for pollination of agricultural crops. Some examples are; e.g., not carrying the colonies to the fields at the proper time nor dressing the bees for pollination; these pose difficulties for good pollination.

Box No 4: Agricultural Perspective Plan of Nepal and Possible Linkages with Managed Crop Pollination (MCP)

The APP makes agriculture central to accelerated growth in Nepal. Increasing farm incomes through high-value crops is an acknowledged process for transforming agriculture. Most marginal lands will be put under perennial fruit cash crops of various kinds to improve their productivity; an ecologically and economically sustainable measure. APP intends to generate employment directly and through multipliers to non-farm rural employment. The strategy of managed crop pollination (MCP) using bees has the potential to play a central role in achieving these goals through defined strategies, inputs, outputs, and impacts. The relevant components of APP with potential to bring about benefits through linkages with MCP are as follow.

APP	MCP
I. Strategy: Urgent acceleration of agricultural growth; principles and strategic priorities	MCP as a strategic priority
II Priority inputs: Technology:	
- research and extension priorities	Incorporate MCP
- seed production	Need to incorporate MCP to ensure quality seeds
III. Priority outputs: high-value crops and agribusinesses:	MCP has a major role in maintaining quality and quantity
- commodity priorities	Cash crop farming needs integration with MCP
- investment and policy	MCP requires an explicit policy (not much investment)
- environment	*Positive contribution*
- agribusiness integration	Positive contribution
IV.Impact: poverty alleviation and food security	
- agricultural growth, employment	
- food security and nutrition	
- supplementary activities	
- better land use	MCP can make a useful contribution in each of these areas
- resource management	
- prioritised productivity package	
- income generation and poverty alleviation	

To counter this, it will be necessary to formulate strategies for wider use of managed crop pollination so that economic incentives for pollination services are made available according to the crops. This will encourage apiarists to prepare beehives of suitable strengths for pollination and better management of organisational work for pollination. The laborious work of increasing the strength of beehives for the pollination of orchards, with restricted nectar productivity from fruit plants, should be paid higher rates than work with crops such as sunflower that produce two to three times more nectar than fruit crops and which are pollinated with less effort on the part of apiarists. Seed-producing crops secrete even less nectar than orchards. In addition, these plants are visited less by bees unless special measures are taken to improve their flight activity.

The roles of regional and international institutions such as ICIMOD, the World Conservation Union (IUCN), World Wildlife Fund (WWF), and the Food and Agriculture Organisation (FAO) are important in the context of bringing awareness, supporting human resources' development, and carrying out policy research, leading to augmentation of the capabilities of national and provincial R&D institutions.

To sum up, we reiterate that adequate results from scientific experimentation and some experiences of managed crop pollination with honeybees are now available. These findings amply demonstrate that this is an effective and cheap biological means to improve and maintain the productivity of mountain agriculture. Further refinement of the technique might be necessary to make it acceptable to farmers in each agro-ecozone, in diverse farming environments, and for specific crops. Initiative is needed to make the potentials of managed crop pollination known to a wider group of stakeholders.

Integration of managed crop pollination as a component of agricultural development strategies is missing. So, to bring it into mainstream agronomic practices, managed crop pollination will have to fulfill other prerequisites of policy, research, extension support, and, above all, farmers' awareness of the benefits of managed crop pollination must be ensured.

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The Centre was established in 1983 and commenced professional activities in 1984. Though international in its concerns, ICIMOD focusses on the specific, complex, and practical problems of the Hindu Kush-Himalayan Region which covers all or part of eight Sovereign States.

ICIMOD serves as a multidisciplinary documentation centre on integrated mountain development; a focal point for the mobilisation, conduct, and coordination of applied and problem-solving research activities; a focal point for training on integrated mountain development, with special emphasis on the assessment of training needs and the development of relevant training materials based directly on field case studies; and a consultative centre providing expert services on mountain development and resource management.

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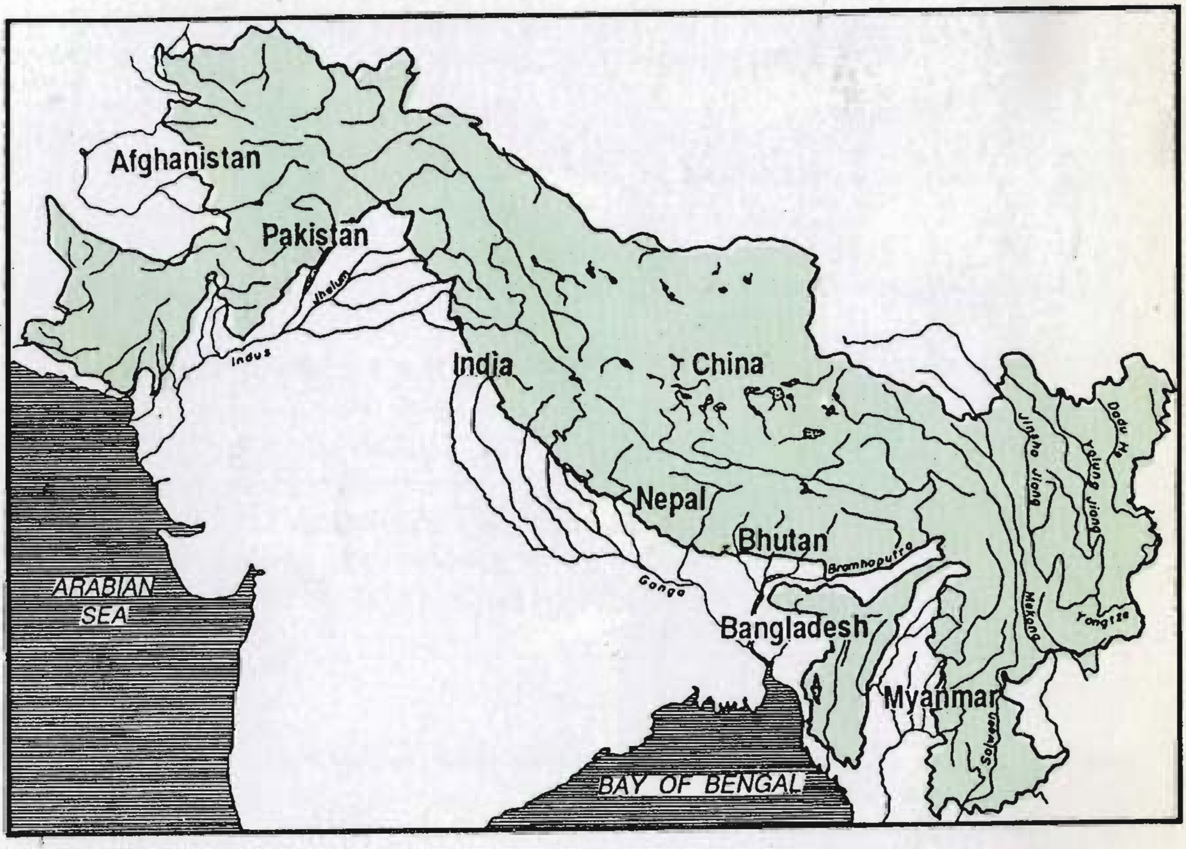
Mountain Farming Systems constitutes one of the thematic research and development programmes at ICIMOD. The medium-term objectives of the programme include i) Appropriate Technologies for Sustainable Mountain Agriculture, ii) Institutional Strengthening for Mountain Agriculture, iii) Integration of Gender Concerns into the Development of Sustainable Mountain Agriculture, iv) Agricultural Research Networking, and v) Better Understanding of Sustainability Dimensions.

Participating Countries of the Hindu Kush-Himalayan Region

- Afghanistan
- Bhutan
- India
- Nepal
- Bangladesh
- China
- Myanmar
- Pakistan



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