BIODIVERSITY IN HOMEGARDENS

TOWARDS A VIABLE CONSERVATION STRATEGY

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1. Introduction

Home gardens in wet-tropical regions such as Kerala, had sustained a high degree of biodiversity in the following three forms: genetic diversity within individual crop or plant species; species diversity among plants; and genetic diversity among domesticated animals and organisms such as pests and insects. However, the diversity of home gardens has eroded considerably during the last three to four decades[1]. There is a need to consider the possibilities of, and the strategy for, the conservation of biodiversity in home gardens, mainly for the following two reasons: (a) There is a general erosion of biodiversity in other cultivated and non-cultivated lands and hence it may be beneficial to preserve the limited level of diversity that exist in home gardens; and (b) Some forms of biological and genetic diversity are best preserved in such an interacting context like a home garden, and hence its disappearance may pose a threat to the existence of such diversity.

A detailed analysis that would be helpful for the design of a viable conservation strategy of the biodiversity in home gardens is very much needed. This is so due to the limitation of the existing studies on home gardens. The literature on home gardens can be summarized as follows. There is a large set of work, starting from the historical accounts of foreign visitors to the tropical countries centuries ago and of the colonial administrators and missionaries, to the studies made by environmental and farming-system researchers in the last two decades of the twentieth century, and this whole set can be categorized as the 'inventory' of home gardens. [For example, descriptions of Kerala home gardens can be seen in historical sources such as Logan (1906), Mateer (1883) and Nagam (1906), and agro-forestry studies such as Nair and Sreedharan (1986), Salam and Sreekumar (1991), Jose and Shanmugaratnam (1993), Kumar et al (1994), Nair (1979), Nair and Krishnan Kutty (1984)]. The agro-forestry studies have also analysed the bio-structure of home gardens, nutrient cycling and recycling, the level of biodiversity and the interaction between the different components in home gardens[2]. A few studies such as Nair and Sreedharan (1986), Santhakumar (1996), Mergen (1987) and Soemarwoto (1987) have also catalogued the factors affecting the biodiversity in home gardens. These factors include market integration, labour shortage, population pressure, and land-holding size. There are a few studies, which attempt to understand the influence of economic forces and the policies on home gardens (Soemarwoto, 1987; Wiersum, 1982; Santhakumar, 1996). However these studies have not led to an understanding of the factors that determine the gap between socially desired level of biodiversity, and what is conserved by the farm-families based on the consideration of their own benefits. Such an understanding can guide the design of policies for bridging that gap and to encourage the farmers to conserve biodiversity to meet the social objectives. This is important due to

[1] For a description of the changes in the biodiversity of home gardens in Kerala, see Santhakumar (1996).

[2] A detailed review of the research on home gardens is given in Millat-e-Mustafa (1998).

the fact that the conservation of diversity in home gardens has to depend necessarily on the farmers' decisions, unlike other resource areas like forest where the state has a dominant role in deciding the nature of its utilization. Thus the analysis of the strategies required for home gardens might require an extension of the concepts that are being used currently to design policies for the conservation of biodiversity[3]. This paper is a modest attempt in that direction.

It starts with a brief description of the nature of home gardens, and its role in the preservation of biodiversity. (This part is intended to be very brief due to the availability of a large number of studies dealing with these issues[4]). However a listing of the major features of home gardens based on other studies is provided in this section in Table 1. This is followed by an analysis of the factors that induce changes in the level of this biodiversity, based on the experience recorded from different regions within and outside India. An attempt is then made to outline the features of a policy framework that may be helpful in the conservation of home gardens, in section 4.

The paper is not based on any fresh primary information or data collection exercise, and is empirically based entirely on the review of secondary information and other studies. It should be admitted that a greater reliance is placed on the empirical evidence from the Kerala state of India, from where this author has first-hand experience.

It should also be noted that the discussion in this paper is exclusively oriented to the conservation of home gardens as a means of preserving biodiversity. However, home gardens may be important in other respects, and may have to be conserved for other reasons. For example, such gardens can be considered as part of natural or cultural heritage, and are valuable in that regard and merit conservation. However such considerations are beyond the scope of this paper.

2. Home Gardens and On-farm Biodiversity

Home gardens, are mixed farming systems comprising seasonal and perennial crops, plants and trees, and with a variety of animals and organisms such as pests and insects, sustained in the land surrounding the house. On reviewing the definitions given by a number of researchers, Millet-e-Mustaffa (1998:13) defines home gardens as the land surrounding a house on which a mixture of annual and perennial plants are grown, together with or without animals, and largely managed by the members for their own use or commercial purposes. Fernandez and Nair (1986) view home gardens as "land-use practices involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and invariably, live stock, within the compounds of individual houses, the whole crop-tree-animal unit being intensively managed by family labour". Based on these definitions, and our interest in home gardens as a means of protecting biodiversity, we can arrive at some minimal characteristics required for defining a system as home garden. The presence of a number of perennial plants and trees around the house can be taken as this minimal requirement. Thus if the land is used exclusively for cultivating multiple seasonal crops, then it may not qualify to be categorised as a home garden. Similarly, there is an issue of whether the land sustaining multiple plants and trees without the house, would become a home garden. Some authors such as Godbole (1998) have included such lands too under home gardens. However the criteria here should be how closely a household manages the cultivation in this land, even if it is not living there.

Home gardens were developed and sustained by farmers in many regions in the past due to the fact that these were then the most beneficial forms of cultivation or land use, given the constraints and

[3] It is surprising to note that concepts of environmental economics are yet to see an application in the case of home gardens. A search in a comprehensive data-base such as ECONLIT showed 139 published articles carrying the economic analysis of biodiversity, and there is not even a single article that deals with the biodiversity of home gardens.

[4] The reference cited in note (2) carries a long list of studies covering these issues of home gardens.

opportunities encountered by them. Such systems were mostly prevalent in humid or sub-humid tropical areas such as South-East Asia (Soemarwoto and Soemarwoto, 1982; Wiersum, 1982), Kerala (Nair and Krishnan Kutty, 1984; Nair and Sreedharan, 1986; Jose and Shanmugaratnam, 1993) and North-Eastern states of India (Godbole, 1998), Bangladesh (Millat-e-Mustafa, 1996) Southern Mexico (Gleissman, 1984) and Central American countries such as Guatemala (Rico-Gray et al, 1990; Anderson, 1950), Amazon basin (Padoch and Jong, 1991), and wet-tropical Africa (Mergen, 1987; Rugalema et al, 1994)[5]. The establishment and sustenance of this system could be attributed to the traditional farmer's realization that such a mixed tree-cum-crop plus animal system of agriculture was more rewarding than the mono-crop or mono-species cultivation, due to the conditions then prevailed in such regions. These conditions include the rainfall and other climatic features such as topography and natural diversity (Gleissman, 1990), and the generation of highest amount and variety of food and other materials for livelihood requirements such as house construction and health, and also for generating cash income through market transactions in the past. The major characteristics of such gardens all over the world, noted by other studies, are listed in Table 1 and some common varieties of plants and trees visible in a typical home garden of Kerala are listed in Table2.

Table 1: Major characteristics of home gardens

PLANT DIVERSITY	
Personal preferences and attitudes, socio-economic status and culture often reflect the appearance, structure and function of the home gardens.	Christanty, 1985
Spatial arrangements of plants in a home garden is always determined by various factors such as light, water, fertility requirements, security and crop protection, health, aesthetics and efficiency of space utilisation.	Christanty, et. al, 1986; Ahmad, et al Sommers, 1978 Wickramasinghe, 1992
Selection of plants grown is dependent on specific community needs, e.g. certain very hot chilli varieties with high capsaicin content are only cultivated in Lotha and Konyak Naga home gardens	Godbole, 1998
Aesthetic importance of home gardens with many ornamental plants and orchids	Godbole, 1998
Personal choice combined with external forces affecting diversity	Mergen, 1987
338 species were found in gardens in one village in Mexico	Buyilla Roces et al, 1983
70 species counted in one garden in Bangladesh	Chambers et al, 1989
Forest trees such as aguillaria agallocha are domesticated in Konyak home gardens in North-East India	Godbole, 1998
154 plant products used in local diet have been reordered in Konyak home gardens	Godbole, 1998
191 species in one garden in Java with 37 species of fruit trees, 21 herb species, etc	Mergen, 1987
500 species were encounted in a village in Java	Michon, 1983
29 useful species in one garden in Peruvian Amazon	Padoch and Jong, 1987
More than 600 species found in both seasons in garden ranging from the highlands to the low lands of Java	Soemarwoto, 1989
More than 120 plant species found in large spacious home gardens	Godbole, 1998

[5] There were also efforts to propagate such agro-forestry systems in such climatic regions where some form of shifting cultivation is practiced as in the North-Eastern States of India. See Jha (1997).

ANIMAL DIVERSITY	
Animals found as part of home gardens	Fernandes et al, 1984 Asare et al, 1985 Brierly, 1985 Soemarwoto et al, 1985 Nair and Sreedharan, 1986 Leuschner and Khaleque, 1987
Animals are regulating agents	Fernandez, 1984
Weld fauna in pollution and seed dispersal in Sumatra gardens	Michon et al, 1986
EROSION OF DIVERSITY	
Reintroduction of mixed crops when price of one crop declined	Chacko, 1991
Social attachment to home garden and linkage with culture are changing very quickly. The choices of species to be cultivated in home garden is no longer dependent on the social and optimal needs of livelihood and house building. It is directly driven by market forces	Godbole, 1998
Farmers resort to greater intercrops to sustain production level, since monocrop coconut plantations are affected by root wilt diseases	Nair and Sreedharan, 1986
Migration leading to non-availability of labour to take care of home gardens	Oduol and Aluma, 1990; Fernandez, 1984
High capital availability leading to monocropping	Okafer and Fernandez, 1987
Tendency to have more ornamental plants and commercial varieties of fruit trees at the expense of more traditional elements of home gardens	Rico-Gray et al, 1990
Better financial position leading to fewer food crops and more ornamentals; scarcity of labour leading to more labour saving perennials; proximity of markets leading to cash crops; and other factors include population pressure, size of land holding	Soemarwoto, 1987
Genetic erosion in home gardens - 75 varieties of Mango reported in one area of Java in 1920s, only one remaining nowadays	Soemarwoto, 1987
Threat of loss of species diversity	Soemarwoto, 1987
FUNCTIONS OF DIVERSITY	
Diversity can harbour both pests and their natural enemies.	Altieri et al, 1987
Gardens used for testing and observing new cultivations and species combinations and for domesticating wild plants	Chambers et al, 1989; Fujisaka and Wollenberg, 1991
Diversity a safeguard against pests and diseases	Fernandes et al, 1984 Mergen, 1987 FAO, 1989 Millat-e-Mustafa, 1996
Valuable gene pool for breeding and improvement programmes	Michon et al, 1983
Multipurpose tree crops provide shade, living fences, fodder and mulch, bee forage, fuel wood, fruit, timber and poles; food for home consumption and sale, protection against pests, cash crops, medicines, spices, mushroom, fibres for ropes and mats, ornamentation	Millat-e-Mustafa, 1998
Gardens being used as informal experimentation stations for new varieties and exotic species	Ninez
Helps to spread farm work, output and income more evenly through out the year	Ninez, 1984

Gardens as away a preserving species uneconomical in field production, and land races of vanishing cultivars are found solely in Andean gardens	Ninez, 1987
Repository and testing site for uncommon species and varieties of plants	Padoch and Jong, 1991
Providing different energy requirements of family for cooking, heating, lighting (with plant based oils) and mechanical energy (by feeding non-edible biomass to cattle)	Santhakumar, 1996
Risk of losses spread among many species	Soemarwoto, 1987
Diversity reduces soil erosion	Young, 1989; Soemarwoto, 1987
INPUTS AND OUTPUTS	
Crops are not producing at maximum capacity but total production is greater and more diverse, with risks minimised and greater long –term sustainability ensured	Altieri and Farrel, 1984
Legumes planted for nitrogen-fixing	Balasubrahmanian and Egli, 1986
Small daily harvests can be made year round for immediate home consumption	Michon, 1983; Okafer and Fernandes, 1987 Buyilla Roces et al, 1989 Millat-e-Mustafa, 1996
Low capital input, simple technology and intensively managed by family labour. Yields are generally low but stable and sustainable	Fernandez and Nair, 1986; Ninez, 1987; Soemarwoto, 1987
STRUCTURE OF HOME GARDENS	
Predominance of fruit and food producing species in the home gardens of respective countries	Barrau, 1991 McConnel and Dharmapala, 1973 Summers, 1978 Michon et al, 1983 Boonkird et al, 1984
Litter contributing to nutrient cycling	Buyilla Roces et al, 1989; Ninez,1987
Canopies of home gardens consist of between two and six strata	Millat-e-Mustafa, 1996
Intensive use of cultivated space, the multiple functions of farmyard plantings, and predominance of root, tuber and tree crops are some of the characteristic traits of traditional home gardens	Ninez, 1987
Percentage of number of species and number of plants were highest in the lowest layer and lowest in the upper layer	Soemarwoto, 1987
Gardens with perennial crops store a greater part of nutrients in the vegetation, leading to nutrient cycling via the litter and a relatively small hazard from leaching and erosion.	Wiersum, 1982
ROLE OF WOMEN	
Woman spent 9.4 percent of their productive activities in the home gardens while men spent only 2.3 percent of their production activities	Ahmad et al, 1980
Women could name 29 plant products form home gardens while men could name 12 such products only	Godbole, 1998

Source: Compiled by the author from Godbole (1998), Mellat-e-Mustaffa (1998), and Santhakumar (1996).

Table 2: Common Trees and Plants in Kerala Homesteads

Name of the tree or plant	Uses
Mango *(Manginfera indica)*	Fruit, timber, non-staple food, organic manure
Silanti *(Tespesia populnea)*	Timber, organic manure, support for wines
Erukku *(Caotropis giganta)*	Organic manure, support
Avarum *(Cassia auriculata)*	Organic manure, support
Laurel *(Calophyllum inopphullum)*	Non-edible oil, organic manure
Jack *(Autocarpus integrifolia)*	Semi-staple food, fruit, timber
Anjil *(another Autocarpus species)*	Timber
Coconut *(Cocos nusifera)*	Several uses
Tamarind *(Tamarindus indica)*	Spice
Tree cotton *(Gossypium arboreum)*	Silk cotton
Yam *(Dioscorea esculanta)*	Tuber (semi-staple food)
Chempu *(Colocasia atiquorium)*	Tuber (semi-staple food)
Elephant Yam *(Typhorium tricobatum)*	Tuber (semi-staple food)
Pepper *(Piper nigum)*	Spice (semi-staple food)
Ginger *(Zingiber officinale)*	Spice (semi-staple food)
Turmeric *(Curcuma longa)*	Spice (semi-staple food)
Plantain (several varieties of *Musa sapientum)*	Fruit, semi-staple food

Source: Santhakumar (1996)

Home gardens were catering to the different requirements of the farm family in terms of food, building construction, health, energy, and culture (i.e., religious and ritual needs). Even for items such as fuel-wood and other tree products for which many societies were usually depending on non-agricultural lands and forests, home gardens catered to a major part of these requirements wherever they were sustained[6]. In addition, generation of cash income through the marketing of products (and/or procurement of other household necessities through the bartering of products) yielded from home gardens, was also prevalent at least during the last couple of centuries. For example, pepper trade was prevalent for many centuries in Kerala, without its commercial cultivation in plantations[7]. Similarly, the mid-land[8] Keralites had been acquiring items such as salt, fish and clothes by bartering garden products even much before the circulation of money in that society.

[6] Wickramasinghe (1995) notes that 50 per cent of the tree products in rural Bangladesh was obtained from home gardens. Thampi (1983) has observed that around 45 per cent of the fuel-wood needs of mid-land Kerala is met by homesteads.

[7] For a description of this long-distance trade of products such as pepper collected from places of habitation in Kerala can be seen in Kieniewicz (1969, 1984). A agro-ecological interpretation of historical change in Kerala can be seen in Santhakumar and Rajagopalan (1993).

[8] Kerala State is divided topographically into three parts: Coastal land, midland and high land. Home gardens are more visible in midland - the land lying between coastal areas and high ranges.

In addition to the generation of multiple products, the agro-forestry systems such as home gardens were also performing valuable ecological functions at the level of the farm and also for larger system such as watershed. These functions are in terms of affecting solar radiation, runoff, and the movement of air, soil and nutrients (Farrel, 1987). Such influences on soil characteristics, microclimate, hydrology, and other associated biological components can enhance the productivity of a given agro-ecosystem. The species diversity that exist in home gardens and other such polycultures, are also claimed to have beneficial aspects in terms of pests and diseases (Altieri, 1987). This may be due to greater mortality of specialist and generalist insect pests due to the abundant availability of insect predators and parasites. It may be also due to the possible presence of host and non-host crops in the home gardens.

These farming systems which were catering to the multiple requirements of farm-families having different characteristics (in terms of family size, land-holding size, labour availability, cultural and health requirements and so on) have sustained a high degree of diversity in terms of species, and genetic variety within a species. Statements such as '37 fruit species were found in one home garden' or '127 plant species are found in large home gardens' (Godbole, 1998) and '72 varieties of mangoes were located' are very common in studies that took inventory of species and genetic varieties in home gardens. Different studies noted the number of species ranging from 20 to 600 in such gardens[9]. More technical measurements[10] of species diversity were carried out in Kumar et al (1994), Abdoellah and Isnawan (1980), Christanty (1985), Brierley (1985) and Rico-Gray et al (1990). One study in Kerala noted that the diversity index for home gardens ranged from 0.251 to 0.739, suggesting its floristic diversity as moderate to low compared to a value of over 0.90 for the species-rich evergreen forests (KAU, 1994:155). There was also considerable diversity in domesticated animals. It was noted that the traditional varieties of cattle were sustained by some farm-families even in the nineties in spite of the widespread use of cross-bred cattle in Kerala (Santhakumar, 1993). The preference for those varieties that can be sustained on home grown feed and materials, and other entitlements, has caused the prevalence of such cattle in some households of the state. Though a number of studies such as Godbole (1998), Chambers et al (1989), and Fujisaka and Wollenberg (1991) have noted that forest or wild plants were domesticated through home gardens, this author could not trace much information on the extent of wild plant and organism (such as pests and insects) diversity that exist in these gardens.

The biodiversity that existed in home gardens was not exclusively due to natural selection, but also the outcome of human intervention for a very long time. The tastes and preferences of several generations of human beings, coupled with the opportunities and constraints encountered by them in terms of cultivation and crop-husbandry, might have got imprinted in the species and genetic diversity that existed in home gardens. Studies have cited instances of better financial position leading to fewer food crops and more ornamentals, scarcity of labour prompting to grow more labour-saving perennials, and market integration leading to dominance of marketable crops (Soemarwoto, 1987). But many such influences need not be one dimensional or static, as evident from the fact that there were ups and downs of intensive cultivation of mono-crop or seasonal crops in such gardens, as people got more and more integrated into wider systems of development. For example, there was a period of increase in cassava mono-crop cultivation to the detriment of mixed farming in Kerala in the sixties and early seventies[11], which then gradually declined, causing a re-emergence of a limited mixed cultivation of cash crops in the eighties and the nineties. Thus it is evident that a multiplicity of factors, exogenous and endogenous to the farm-family, influenced the nature of biodiversity in home gardens.

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[9] See, Millat-e-Mustafa (1998), Table.3.

[10] This usually includes the measurement of Shannon's index, which is based on the proportion of a particular species in a sample. For a technical description of this index, see Fowler and Cohen, 1992.

[11] The decline of cassava production is documented in George (1988).

2.1 Importance of conserving the biodiversity in home gardens

The importance of this biodiversity may not be in the availability of some wild or primitive species or varieties as in the case of forests in such tropical areas. (Moreover the wild cousins of the varieties that exist in home gardens may still be available in the remaining forest patches of these areas.) However the importance of the biodiversity of home gardens is in the availability of varieties, which were found suitable to human beings under a large variety of social, economic and cultural situations. And these varieties with such special qualities may have direct or indirect uses in future, and this fact makes them valuable even if their potential uses are currently unknown[12]. There are essentially two sources of value for this biodiversity, one the utilitarian value to be located in the potential future uses of the genetic material, and other as a source of resilience to the agro-ecological system either within the farm or in the locality[13]. If biodiversity in general contributes to the resilience of natural system, the diversity in home gardens may be contributing to the resilience of an agricultural system.

The biodiversity of home-gardens provides important benefits to the farm family, such as the diversity of products, and also other benefits such as controlling soil erosion (Young, 1989). Diversity can also be a safeguard against pests and diseases, as noted earlier (Millat-e-Mustafa, 1996). For example, there is anecdotal evidence that the diseases in two crops namely coconut and pepper that have devastated large areas in Kerala, were less prevalent when these crops were cultivated as part of multi-crop systems[14]. In addition to such direct benefits of biodiversity to the farmers, it is beneficial to the society at large in terms of a storing house of genetic resources. Home gardens may be a way of preserving species, which are uneconomical in field production (Ninez, 1987), or can be considered as gene pools for breeding programs (Fernandez and Nair, 1986; Michon et al, 1983), since a large spectrum of genetic variety, that underwent natural and human selection, may be existing in such gardens. This gene pool might also facilitate participatory plant breeding, which has become an accepted practice for field crops in the nineties[15]. These potential benefits may not be captured fully by the farm-family.

The conservation of the biodiversity in home gardens can also be seen as part of the ongoing efforts of on-farm conservation, which is being currently viewed by some scientists as complimentary to ex-situ conservation of agricultural biodiversity[16] (or the other way around, with in-situ as the main strategy, and ex-situ as complementary to it). On-farm conservation is defined as the continued cultivation (and husbandry) of a diverse set of crop populations by the farmers in the agro-ecosystems where such crop set (or structure) had evolved (Bellon, 1996). The main objective of such on-farm conservation as viewed by these scientists is to maintain the evolutionary process that continues to shape this diversity. This evolutionary process reflects the tastes and preferences of farmers, and the opportunities and constraints encountered by them. At the micro-level, farmers may be adopting or

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[12] This fact that a species or genetic variety is valuable, even if it is not known to be useful with the current level of knowledge, is the basic idea behind the concept of `option value', analysed in environmental economics. For a detailed account of the concept of option value, see Fischer and Hanemann (1997)

[13] A discussion of such sources of value of biodiversity in general can be seen in the papers in Perrings et al (1995).

[14] The virus attack on coconut and pepper became wide-spread after their cultivation as mono-crops, and such attack was not noticed when these were growing as parts of mixed farms. Even today, the virus attack on pepper is more prevalent in high ranges of Kerala, where that crop is cultivated as plantations and less prevalent in mid-land where pepper is only one among a number of crops in the farm.

[15] The issues of participatory plant breeding are discussed in a number of studies, and their reviews can be seen in Sperling et al (1993) or Boef et al (1993).

[16] Thus the conservation of landraces or traditional crop varieties in home gardens is considered as one of the three steps of in-situ management by the report on the *State of the World's Plant Genetic Resources* prepared by FAO (1996).

discarding one or many varieties due to several reasons such as productivity, requirements of the family, climatic adaptation, drought resistance, pest resistance, eating or storing quality, reduced variation in the yield, and so on[17]. The economic factors such as labour availability, market signals, need for supervision, etc. may also influence the variety structure as well as production, yield and income generation. Since there can be variations in the combined effect of all the factors for different farm households, one can expect a variety of crop (and genetic) structures prevalent in a region. Thus the maintenance of on-farm diversity in the home gardens can be taken as the conservation of a biodiversity that has the imprints of several human life-situations.

It is this factor that makes the conservation of home-garden diversity important and different from other efforts to conserve biodiversity. In order to arrive at viable conservation strategies, one should analyse systematically the factors that cause erosion of the diversity in home gardens. Such an analysis is carried out in the following section.

3. Factors Causing Erosion of the Biodiversity in Home Gardens

There is a difference between the factors that facilitate the existence (or cause the erosion) of biodiversity in forests and in home gardens. The lack of intensive human intervention can be a major factor for the prevalence of a high degree of diversity in the forests, especially rain forests, and it has eroded wherever such intervention became intensive. However, the existence of a higher level of diversity in home gardens could be reckoned as a result of more intentional choices made by the cultivators and farm families in certain historical periods. Home gardens might have undergone even phases of diversity enhancement through the efforts of cultivators at different stages of its evolution. Thus the reasons for the erosion, and the policies for the conservation, of biodiversity in home gardens, might be different from that of uncultivated lands such as forests[18]. The basic issue today is that the level of biodiversity that existed in all home gardens at some point of time in the past (and in some home gardens even today) is now reckoned important to be conserved. This is based on the growing realisation that the limited diversity that exists in home gardens is valuable, and this value seems to increase, as there is a general decline in the overall biodiversity. It is also based on the realisation that, society has to positively interact with the farmers to maintain and improve the existing biodiversity. For even those cultivators who sustained a high degree of biodiversity in their home gardens in the past out of their own choice (i.e., without any social or governmental support), may reduce their farm-level diversity on their own from the level desired by the society, due to a number of reasons. This section is devoted to the analysis of these reasons and these can be broadly categorized into three: (a) market failure; (b) policy or governmental failure; and (c) information failure.

3.1 Market failure

The basic issue of market failure[19] is that the level of diversity which is most beneficial for the farmer, need not be the level desired by the society as a whole. There may be a gap between the private

[17] There are several agronomic studies identifying such micro-factors that encourage the adoption of crop genetic varieties. For a review, see Bellon, 1996.

[18] There may be some cases where people husband forest spaces (for example, see Michon, 1983). However here too, the conservation has to depend on making such conservation beneficial to these farmers, since prohibiting their use as being done for conserving other forests may not be ideal or a practical solution in this case.

[19] Market failure is used in a broad sense that the decisions taken by individuals with considerations of their own costs and benefits, need not be the best decisions for the society as a whole when social costs and benefits are taken into account. The discussion of the sources of market failure can also be seen in any standard text book on environmental economics such as Hanley (1997).

benefits of biodiversity to farm family, and the current and potential future benefits that the society as a whole derives from that level of diversity. These farmers usually consider only the private benefits in deciding the extent of diversity that is to be sustained in their land. This may be true even if we consider the group of farmers living in an area or a community, instead of individual farmer. Since the existence of biodiversity may provide benefits to the larger society (i.e., the region or country or the world), the total benefits of biodiversity may be greater than what is derived by the local community or this ethnic group of farmers.

This gap between social and private benefits of diversity can change over a period of time. Markets can induce farm owners to reduce diversity, even when such diversity is valued highly by the society. This has happened when market provided signals indicating a specific genetic variety of a plant, or a specific plant as significantly more beneficial than others, and the technology of such crop-production required the reduction of the cultivation of other less preferred varieties or species. There are several examples in this regard from all over the world. Rico-Gray et al (1990) have noted that home gardens in Andean region have incorporated more ornamental plants and fruit trees in the place of traditional crops due to market integration. Such changes in cropping pattern in home gardens driven by market demand are observed in North East India (Godbole, 1998), South East Asia (Soemarwoto, 1987; Wiersum, 1982), Africa (Mergen, 1987) and Kerala (Nair and Sreedharan, 1986; Santhakumar, 1996). The expansion of rubber cultivation in Kerala is one such case (Santhakumar, 1996). Crops such as rubber require (for profitability considerations) the decimation of other crops from the same land. Temporary market signals indicating higher profitability for certain species such as cocoa, coconut, pepper, or banana, might result in an increase in land allocated towards that crop to the detriment of other species and varieties. The higher price or marketability of a certain variety within a species (say, one variety of banana or mango) work against other varieties, and this can lead to a very significant erosion of variety in crops such as mango or plantain which are known to have existed in large varieties in home gardens in the past.

Income-induced changes in consumption patterns by the farm family, or others in the society also reflect in market signals and can result in the gradual decline/disappearance of certain varieties/species from the home gardens. For example, the reduction of Jack-fruit (or tapioca) varieties in Kerala and other places can be attributed to the reducing importance of them as a semi-staple food (due to the growing preference for rice and wheat)[20]. Or in a different case, the need to grow more food may lead to expansion of cassava, as happened in some parts of Indonesia (Wiersum, 1982). Signals leading to the reduction of biodiversity emanate not only from commodity markets, but also from labour markets. The increase in wage rates relative to commodity prices would result in the non-cultivation of (or the reduction of area under) several crops. This pattern would become more prominent where cultivation or crop husbandry, require wage labour, or where both wage labour and family labour have more profitable opportunities in non-agricultural occupations. This has occurred in the case of several seasonal crops such as black gram, sesamum, betel-vine, and coarse cereals nurtured in the home gardens of Kerala[21], and led to the non-availability of a large number of traditional varieties of such crops in the home gardens. It is also noted that labour shortage prompts farmers to grow more labour-saving perennials such as coconut (Soemarwoto, 1987; Unni, 1981; Kuttappan, 1981). It is not only the cost or non-availability of wage labour that influence these changes, but also the fact that members of the farm family find it less profitable to spare their time on supervising the cultivation or nurturing of these crops too[22]. [However, this change driven by the lack

[20] The use of cassava or jack-fruit as a semi-staple food comes down as there is an increase in the per-capita income in the society, because these are considered inferior goods. See George (1988) for a treatment of cassava.

[21] It is these conditions have also resulted in the decline of paddy cultivation in Kerala. See George and Mukherjee (1986).

[22] The impact of the increase in the opportunity cost of time used by the family labour to supervise farm operations is analysed in Santhakumar (2000). The tendency to grow trees by the supervision-constrained farmers has been noted in other agro-climatic zones too (Saxena and Srivastava, 1995).

of time for supervision can sometimes lead to the reduction of the cultivation of seasonal crops (which require more labour and supervision), and the increased reliance on perennial crops or trees that need less labour. This is discussed in detail in the next section.]

Like the labour market, capital market too influences the nature of cultivation and hence the diversity in the home gardens. It is noted that the availability of finance (through loans) might induce farmers to cultivate cash crops, which are in high demand (Soemarwoto, 1987). This pattern was also observed in parts of Africa, as noted by Okafor and Fernandes (1987), where oil boom had led to some farmers clearing their gardens with bulldozers for the intensive cultivation of mono-crops. Development of capital market and insurance mechanisms also might result in the reduction of the risk-bearing role of homestead cultivation (with a variety of crops to reduce risk) or the savings role performed by the trees[23] (by way of generating cash income during emergencies through cutting down trees).

Indirect influence of these market signals can be the reasons for some changes in home gardens, which might look like they are due to certain cultural or social factors. For example, the increase in the opportunity cost of time, and the availability of medicines and medical help in the nearby locality, which reduce the time of treatment for certain illnesses, might encourage farmers to depend on such medical help and reduce their dependence on herbal remedies available at their home gardens. This may eventually reduce the practice of nurturing such plants in their farms. (This can be interpreted as an increased attraction towards modern medicine, in spite of this underlying economic rationale).

In summary, signals emanating from commodity, labour and capital markets have a strong influence on the level of biodiversity in home gardens. An important issue here is that whether such market signals encourage farmers to neglect the benefits of biodiversity, which they themselves can capture in the long run. (These benefits include safeguard against disease and pests, multiplicity of products, reduction of soil erosion, and so on). This issue is not taken to be part of market failure by the economists. Thus we consider this issue more elaborately in the section of information failure, and in this section of market failure, our assumption is that the farmers are capable of assessing the private benefits of biodiversity.

However, there can be another source of market failure (other than the fact that there is a gap between private and social benefits) that aggravates the individual's inability to consider his own benefits of biodiversity even when he is informed. This arises out of some sort of irreversibility[24], due to the fact that if some varieties or practices are abandoned at some point of time, their replacement at later point of time may become very expensive, even if the farmers wish to do so with the considerations of private benefit. This may be due to the fact that these varieties or practices are simply not available there any more. Such increase in the cost of re-establishment becomes more prominent if many or all farmers abandon some variety in a locality at some point of time. This cost of irreversibility may not be fully accounted by the cultivators even if they are aware of the private benefits of biodiversity in home gardens.

The gap between social and private values of on-farm diversity may widen even when the farms continue to have the same diversity, if there is general erosion of diversity in other lands, and thus there is a general increase in the demand for conserving biodiversity. Thus what society would be willing to spend (say, in terms of subsidy) for protecting diversity in home gardens may be more today than what would have been in the past, or would be increasing in future times.

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[23] Such role for trees in rural farming systems is well acknowledged in literature. See, the papers in Arnold and Dewees (1997).

[24] For a discussion of how irreversibility influences investment decisions, see Dixit and Pyndick (1994).

The discussion so far might have given the impression that the secular trends in commodity, labour and financial markets would always result in a decline in the biodiversity of home gardens. This is not true. In fact, there are market signals that encourage the enhancement of diversity, even though the level of diversity attained through such market signals may not be up to the requirement of the society. The following section carries a discussion of the diversity enhanced through market interactions. The understanding of this issue is important for effectively using market signals for enhancing biodiversity wherever these are appropriate.

3.1.1 Market-driven increase in diversity

The popular belief among some environmentalists that market always provides signals preferring mono-crop or mono-variety cultivation[25] is wrong. Markets too can sustain some level of diversity in home gardens, and this can happen due to several factors. A more apparent reason is the increasing demand for multiple products that can be produced in home gardens. These products come from not only the different species, but also different genetic varieties within a species, sustained in gardens. Such market driven diverse-cultivation in home gardens have been observed in many parts of the world including North East India (Godbole, 1998) and Kerala. For example, a typical home garden in modern day Kerala could sell a large number of products such as, coconut, plantain, banana, pepper, cashew nut, mangoes, jack-fruit, tamarind, and so on to local, national and/or international markets. If we take a sufficiently long period (say a decade), one can see phases where either one or other product in the above set, getting a profitable price[26]. The fact that these products come from more or less perennial plants, and that these grow without much competition in the agro-climatic conditions of Kerala, do encourage a number of farmers to sustain these multiple species and a number of varieties within each species. It is noted that in recent times the process of adding trees has accelerated all over the developing world by the expanding markets for fuel wood and other tree products, and the consequent emergence of the growing of trees as a cash crop (Arnold, 1997). However this factor need not enhance crop diversity within the farm to the extent desired by the society.

It can be seen that the demand for products coming from home gardens has high-income elasticity, unlike food grains, whose demand may become stagnant as income grows[27]. This is due to the fact that people consume more of such diverse products like fruits, nuts, etc. as their income grows, where as there may not be any significant increase in the amount of food-grain consumption after reaching a particular level. In that sense, farmers who sustain home gardens are in better market-position than those who intensively cultivate food grains with the use of fertilizers and the other components of green revolution package. This is true not only for the international market, but also for domestic and local consumers. Consumers who start eating non-staple commodities, such as fruits, tend to move (as they go up in their income ladder) towards the consumption of a diverse set of fruits, rather than the mass-produced fruit of standard features. The highest level of this 'new food pyramid' is known for the consumption of organic or naturally grown products[28], which is estimated to cover 1 to 2 per cent of food trade in developed regions such as Europe. The demand for such nature-based products is

[25] This is part of the general tirade against trade and markets by some environmentalists. For example, such a position in broad terms is articulated in Shiva (1995).

[26] It is also noted in field experiments that promoted home gardening, that when income generation is the objective, a diverse supply of products tends to have more secure market value, especially during the off season (Marsh, 1994).

[27] It is well known that cash crops such as pepper, cashew, etc., have higher income elasticity than the food grains. By taking this, together with the fact that food grains are generally cultivated as mono-crop, and a number of cash crops including those mentioned above were grown in multiple systems, one can say that markets in the long-run provide signals favourable to home gardens, rather than to the mono-crop cultivation of food grains.

[28] The expansion of organic food industry and farming is discussed in Hall (1989), Molder et al (1991), and Marshall (1991).

increasing all over the world as evident from the trend of other related products and services such as `nature-based' tourism[29].

Markets can also sustain, or emanate signals to enhance, diversity due to other factors arising out of the complex interaction between labour, commodity, land, capital and insurance markets. For example, if the members of a farm-family find it less profitable to spare time to supervise cultivation in their own farm, this can under some conditions encourage the 'growth' of diverse set of plants and trees, and discourage the 'intensive cultivation' of one or two crops (Santhakumar, 2000). This is due to the fact that such increase in the opportunity cost of time, make farmers to reduce the cultivation of seasonal crops (which require more labour and supervision) and grow trees that need less labour and supervision, and in extreme cases to stop cultivation itself and allow the land to have some natural growth of plants. It is observed in Kerala that as human capital development takes place and people find opting for non-agricultural job more beneficial, they are finding a land-use pattern, which require less supervision better for their own land, and such patterns sustain more diversity than the one adopted by some full-time farmers. One can take this as the outcome of labour market development. This is similar to the widely observed phenomenon in the developed world where migration of the landowners from the countryside to urban areas, finally results in the enhancement of forest areas and forest-based biodiversity.

Markets emanate other signals too, that do not prefer a mono-variety or mono-crop technology. For example, if farmers are allowed to respond to market signals properly, they may even reject modern varieties, based on their assessment. This can happen if such a modern variety, popularised by the governmental or other agencies and whose cultivation can potentially lead to its dominance, does not seem to be profitable in the long run. Thus the Kerala farmers have not adopted the high yielding variety of coconut, and still depend on the so called traditional varieties, because they yield for longer durations albeit at lower levels and can withstand variations in moisture level, compared to the modern variety which provides high yield on regular irrigation and yields little, if there is a break in irrigation (Sivanandan, 1985; Narayana, 1991; Santhakumar and Rajagopalan, 1995). Thus the markets if left free (without trying to change the behaviour of farmers with very high subsidies and so on), would provide certain signals that encourage diversity, and hence market-integration need not be viewed as inevitably inimical to sustenance of biodiversity. Of course, it is clear that the privately beneficial level of biodiversity that is decided on the basis of market signals need not be equal to the level that is socially beneficial, and thus the need for social intervention.

However it can be seen that the interventions by the government for meeting some social objectives are not necessarily beneficial for biodiversity conservation. These issues are discussed in the following sub-section.

3.2 Policy or governmental failure

If market provides mixed signals, policies and governmental actions in India tend to be mostly inimical to the sustenance of biodiversity in home gardens. This has arisen out of the unintentional consequence of the policies, which were followed by the successive governments in India during the post-independent period. The policies that aimed at making food grains available at cheaper prices, through interventions in market, provision of subsidies, and the subsidized extension of technologies that favour the intensive cultivation of mono-crop (or mono-variety), were used not only for food grains and cereals which were traditionally cultivated as mono-crop, but also for crop/plants which were nurtured in mixed systems such as home gardens. There were attempts to provide crop-based (or

[29] A discussion of the growth of nature-based tourism and its role in biodiversity conservation can be seen in Gossling (1999).

even variety-based) subsidies for planting, nurturing and marketing for coconut[30], cashew, pepper[31], and so on, which were usually earlier maintained with multiple varieties in mixed systems. [Of course, the final outcome of this subsidized extension depended on whether farmers found these propagated varieties profitable, even after taking into account the subsidies, and they might have rejected some of these new varieties with their own assessments of profitability, as it has happened in the case of coconut (Sivanandan, 1985).] There is also a high level of subsidies for some crops, whose extension would inevitably result in the disappearance of other trees/plants from the home gardens. This has occurred in the case of rubber, which was extended with heavy subsidies even to small and marginal farms, which were previously sustaining home gardens. It is well known that such subsidies have led to the cultivation of such crops as rubber in areas much more than what is even economically beneficial or sustainable (Harilal and Joseph 1998). Similar impact of agricultural development policies on home garden biodiversity is observed in other parts of the world too. For example, Wiersum (1982), Chambers (1983) and Pacey (1982) have mentioned a number of cases where development workers backed by the government or NGOs imposed a single component approach on many farmers inducing them to shift to monocropping, even in areas such as wet tropical Africa, which traditionally sustained multi-crop-tree systems. It was also noted that many of these attempts failed even in conventional economic terms.

This adverse effect would not have occurred if the subsidies provided as part of these agricultural development programmes were given as a lump-sum grant, instead of giving it for specific crops and operations. This would have avoided the situation in which some crop or variety became artificially more attractive to the farmers, due to the subsidies provided to the crop/variety. In the case of lump-sum subsidies for agriculture (which is justifiable given the adoption of policies unfavourable to agriculture, for the sake of industrial development), different crops and plants (and varieties) would have been selected on the basis of their growth, production and market conditions. The possibility of having a multi-variety mixed system is much more under such a situation of less-intervention by the government in humid-tropical and other related areas, which were traditionally sustaining a mixed system such as home gardens. We have seen in section 3.1.1 that it is not surprising to see farmers nurturing such a mixed system even with the changes in market trends in such climatic zones.

Similarly, there were failures in technology extension made by the governmental agencies, where in varieties and practices that are not very appropriate (even economically) were propagated and imposed through subsidies (Santhakumar et al, 1995; Santhakumar and Rajagopalan, 1995; Santhakumar and Rajagopalan, 1994). The 'success' of green revolution package of food-grains in drier irrigated areas, encouraged scientists and policy-makers to try similar changes in the crops cultivated in home gardens including tree crops. However the experience of green revolution in tree or perennial crops have not been very successful. This was due to many reasons. First of all, even the scientific claims on the superiority of modern varieties of such crops were not realistic, given the fact these were not tested adequately for their superiority over the whole life span of such tree crops (Narayana, 1991). (If a modern variety of coconut has to prove its superiority over traditional variety, these have to be compared for the whole life period of that tree, which can be anywhere around fifty years.) Moreover the farmers' assessment of such long-period crop/tree need not be based on short-term yield of a particular product from the crop. For example, timber value at the end of productive life can be a genuine consideration of farmers, where as that need not be a consideration of scientists who develop modern varieties. It is also a fact that a number of trees and plants have survived and flourished in home gardens mainly due to the specific agro-climatic characteristics of the regions, and the success of modern technology in developing varieties that can flourish in a wide rage of climatic zones, is limited in the case of such local climate-dependent crops. In spite of all these factors, and without enough evidence of superiority, scientists and policy makers have 'imposed' modern uniform varieties of the crops/trees that were sustained in home gardens, accompanied by subsidies and other

[30] For a review of policies on coconut production, see Narayana et al (1991).

[31] The issues on pepper production can be seen in George et al (1989).

incentives[32]. Of course, in some of these cases, farmers have not either fallen into this trap, or could easily get back to the older varieties. However in certain other cases, farmers have moved into newer varieties, and there are no easier options to get back to the older varieties even if they wish to do so. For example, it is not uncommon to see people expressing a preference for certain traditional varieties of mango or cassava but unable to get them due to the disappearance of these varieties from their localities. This is related to the issue of irreversibility discussed in the previous section, and it can probably make going back (i.e., enhancement of diversity) costlier, if farmers have reduced this diversity due to the policy failures. That shows that scientists and policy makers who induce changes in biodiversity should have ideally considered not only the benefits of moving to mono-variety (and modern-variety) cultivation (and we have seen that they have not adequately considered even these benefits in many cases) but also the increasing cost of enhancing diversity if it is found to be beneficial in future.

The property right regimes adopted by governments, even with the objective of conserving environment, may indirectly work against the sustenance or growth of diversity in home gardens. It started with the land-reform regulation that exempted plantations from the purview of land ceiling, as in the case of Kerala[33]. Even the recent regulations such as the inclusion of forest-like growth in privately-owned lands under the purview of Forest Conservation Act of 1980[34], is likely to discourage the adoption of many varieties of trees, and the growth of private forests in their plots, even if they want to do so with considerations of labour shortage and long-term income.

Thus the government or judicial interventions guided by social or environmental considerations need not always result in biodiversity conservation, and in at least certain cases, these can lead to the erosion of diversity.

So far we have considered the erosion of diversity driven by market signals or as the side effects of government policies, and we have assumed that farmers have the ability or information to take decisions that are best suitable for them. However this assumption is unrealistic in many circumstances, and the lack of information may in reality impair the ability of farmers to consider even their own benefits and costs. It is to this issue, that attention is focussed in the following paragraphs.

3.3 Information failure

There are circumstances where farmer's ignorance, or neglect and lack of information have caused the erosion of biodiversity in home gardens, even when they themselves could have gained the benefits of such enhanced biodiversity. For example, it was noted that the lack of replanting of timber trees such as *Anjili* (an autocarpus species) after cutting down older trees from home gardens, has substantially reduced the production of timber from Kerala home gardens (Santhakumar, 1996). Even though this is not a direct instance of the reduction of biodiversity, it showed that even directly useful plants and trees may disappear for the lack of attention by the farmers. A similar situation prevails for the production of organic manure. These can be interpreted as cases of information failure, because farmers failed to consider the long-term benefits of sustaining timber or organic manure trees either due to ignorance or short-sight behaviour. These issues of information failure are aggravated by the

[32] The belief of the scientists and policy makers that the technologies that were found to be useful elsewhere would be beneficial in humid-tropical regions too, had played a major role in this regard. For details, see Santhakumar and Rajagopalan (1995).

[33] A detailed account of land reforms in Kerala can be seen in Raj and Tharakan (1983).

[34] This is the interpretation of the Forest Conservation Act, 1980, given by the Supreme Court of India in the case of T.N. Godavarman Thirumulpad Vs Union of India and others in 1995, wherein it was noted that the provisions made in the act must apply to all forests irrespective of the nature of ownership or classification (Sahasranaman, 1997).

incorrect or incomplete information provided by the scientists and the propagation of half-baked technological packages which were not proven to be superior in the long-run – an issue discussed in the previous section. To some extent, lack of information is a problem not only for the farmers, but also for scientists and the whole world, with regard to the potential use of a genetic resource in future. Ideally, this uncertainty due to lack of information should reflect in the valuation of diversity (i.e., option value), and hence the decisions to change its nature. The information failure on the part of farmers is also caused by the fact that the information on cultivation practices (and plants and trees) were usually transmitted informally through generations, and hence any break in the use of a variety at any point of time can affect the knowledge on that use/variety of the future generations. Thus the tendency among farmers to neglect their own benefits of enhanced biodiversity becomes more prominent in successive generations, since they are not aware, and are not exposed to the diverse plant structure and its uses that prevailed in home gardens. The non-availability of planting materials (and hence the increasing cost of acquiring them), in the surrounding area, as indicated in the discussion of the problem of irreversibility, can also aggravate this information failure.

So far we have conceptually categorized and discussed the factors that cause erosion of biodiversity in home gardens. These discussions should help us in outlining a set of strategies to conserve this biodiversity. Following section is an attempt in that direction.

4. Towards a Viable Strategy for the Conservation of Biodiversity in Home Gardens

The discussion in the previous section showed that biodiversity in home gardens is eroded through the failure of markets and policies, and due to the lack of information. It has also indicated that certain market signals encourage the conservation or enhancement of diversity. Thus the policies for the conservation of biodiversity in home gardens may have to aim at the following four objectives.

(a) Correction of Market Failure

(b) Strengthening Market Signals that Enhance Diversity

(c) Correction of Governmental or Policy Failure

(d) Correction of Information Failure.

4.1 Correction of market failure

There is a case for market intervention to reduce the gap between privately beneficial and the socially desired level of biodiversity. This requires some understanding of what is to be conserved through home gardens (and this may vary between different ecological zones), and what can be cost-effectively conserved through other means. For example, it is to be examined whether the conservation of home gardens can be taken as an appropriate strategy for preserving the wild relatives of the cultivated crops. It seems that this is unlikely given the fact such wild varieties may be available in the remaining patches of the forests in those regions, and it may be cost-effective to protect forests rather than home gardens with this purpose. On the other hand, forest conservation even in rain tropical areas may not be adequate to conserve the genetic base available in home-gardens, since this genetic stock has the imprint of human-life situations as discussed earlier. Thus the first step in designing the strategy to correct market failure is to see what form of diversity is to be preserved through the conservation of home gardens.

It is not adequate to find out the ‘end purpose’ of conserving home gardens, but the potential impact of different ‘means’ of conservation through market correction should also be analysed. This is due to the fact that the particular policy or instrument chosen for correcting the market failure in this regard, may influence not only the cost and efficiency, but also the genetic stock itself. For example, if the instrument (say the provision of some subsidy) is based on the range of genetic variety (i.e., gardens with higher range receiving subsidy), it may induce farmers to artificially enhance variety range and can possibly lead to less attention on some varieties, which have particular qualities that are helpful

for the sustenance of the home garden system. Thus there can be two types of instruments, one that aims at preserving a pre-determined genetic stock, and the other that encourages the sustenance of diversity that is appropriate in the specific farm-family contexts. These two instruments may have to be used in combination or isolation, depending on the necessity of the situation. For example, in a context where home garden diversity has eroded drastically and farmers have gone for more-or-less mono-crop forms of cultivation, it may be necessary to have instruments that encourage diversity per se, and here it may be difficult to choose one element of diversity over the other. Whereas in other contexts in which some level of diversity exists, specific instruments aimed at diversity within certain crop/species or with certain characteristics such as pest control, drought resistance, etc. can be resorted to.

The ultimate instrument for the correction of market failure can be in the form of providing subsidy to those home gardens that sustain a high level of diversity. This subsidy need not be similar to other subsidies that are prevalent in agricultural sector. It can also be in the form of 'prizes' or 'awards' to a limited number of farmers for sustaining a higher-level of bio-diversity in general or with specific characteristics. The number of farmers has to be decided on the basis of factors such as agro-climatic differences and other agricultural situations. Moreover, the need to have at least a minimum number of farmers practising diverse agriculture in an area to sustain it in the long run should also be considered.

There can also be provisions other than subsidy to correct market failure. There can be mechanisms to compensate farmers or group of farmers, if the diversity preserved in their home gardens helps the development of modern varieties or in the development of other products such as medicines. This might require frameworks similar to those advocated (and adopted in certain cases) for sharing benefits of biodiversity prospecting or utilization, between the people living in the forests and the agencies and organizations carrying out such prospecting or the development of diversity-based products.

Thus there can be different ways of correcting market failure with regard to the gap between the private and social benefits of conserving biodiversity in home gardens. However, the selection of particular policy or instrument for this purpose should be based on an understanding of what is to be protected through home gardens (vis-à-vis other resources such as forests), and the impact of particular policy on the further evolution of diversity, and also on considerations of cost-effectiveness.

4.2 Correction of governmental/policy failure

The second course of action is to correct the policies that are harmful to diversity. As noted earlier, there are some policies, which can be corrected without much economic loss (in fact there can be economic gains), as in the case of crops where modern varieties were promoted without a careful examination of their superiority. In fact certain subsidies or governmental policies can be shown to serve no genuine social purpose, but are there only due to self-serving objectives of the bureaucratic machineries in different arms of the government. For example, creation of commodity boards such as rubber boards and their growth with a number of agricultural scientists lead to excessive efforts to expand cultivation of rubber even in uneconomic plots, leading to excessive supply and uneconomic prices. Even in the case of policies, which are aiming at some legitimate social purpose, it may be possible to meet the same objective without creating 'side-effects' such as the erosion of biodiversity in farms. This was evident from the discussion of the possibility of replacing crop/variety-based subsidies with lump-sum grants. It is necessary to avoid excessive encouragement of specific crops/varieties driven by bureaucratic and technocratic interests of the governmental machineries, which are even against the economic interests of the farmers in the long run. The discussion on governmental/policy failure shows the importance of propagating newer technologies or varieties of cultivation, with *lesser* inducements, so that farmers would be able to evaluate them in a realistic manner. This will avoid a situation in which farmers reduce biodiversity in home gardens and go for some varieties for reasons of subsidy or short-run benefits, to the detriment of their own long-term

benefits and societies' requirement of biodiversity. This is not to deny the role of the government in extending information and newer technologies in agriculture, but to highlight that such extension coupled with high inducements and social marketing disables the farmers to judge the new crops/technologies on their true merit. What is needed is a revamping of the technology-extension system in agriculture, where the provision of information regains an important role combined with a declining role for the distribution of subsidies and other compulsive measures.

Policy makers have to be more sensitive to the potential 'side-effects' of some of their innocuous policies, in terms of reducing biodiversity. For example, the clauses such as those in Forest Conservation Act, which discourage farmers to grow forest species in their farms, or even from leaving their farms to sustain a forest-like plant growth need to be removed. This is especially so because, forest growth in private land can be a major factor in extending areas under forest cover during the coming century in countries like India, as evident from the forest growth in the developed countries in the twentieth century.

4.3 Strengthening market signals that encourage diversity

The third course of action can be the strengthening or widening the scope of, those market signals that encourage the sustenance of a higher level of biodiversity in home gardens. The first step in this direction should be to extend and deepen the currently limited but growing market for 'nature' or 'organic' products at the domestic and international levels[35]. The non-governmental and other concerned organizations can play an important role in spreading and networking this growing market and also to help both producers and consumers. The growing openness in international agricultural trade should be seen as an opportunity to tap the 'nature' market in developed countries in Europe, America and East Asia, by the multitude of small farmers who sustain some forms of diverse agriculture. Lessons from similar experiments going on in other countries[36] such as Thailand, Malaysia and Japan should be learned and such knowledge would help us in forging new networks and alliances for this purpose.

It may be possible that stringent adherence to environmental regulations in developed regions like the restrictions on pesticide-ridden agricultural imports by European countries, would further encourage the sustenance of biodiversity in developing world. This would help the farmers to rely on traditional practices of pest resistance and diverse cultivation is one such practice. It may be noted that certain crops such as pepper and coconut became more vulnerable to diseases as these have moved from mixed farms to mono-crop plantations.

4.4 Correction of information failure

Even with all these measures discussed above, farmers may not be able to take informed decisions on conserving biodiversity. This is not surprising since information on such environmental decisions is inadequate at the local, national and even at the international levels. The issue of irreversibility, and the high cost of replacing a variety if it is lost, should encourage a more cautious decision and hence any decision on the basis of inadequate information can be costly. Thus there is a definite role for the spread of information, awareness and other campaign programs. It is here that a large number of non-governmental organizations involved in biodiversity campaigns can play an important role.

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[35] In spite of a decline in the international agricultural trade, this `organic' or `natural' sector is rapidly growing in the nineties. For example, trade in organic banana has grown more than 30 percent in the late nineties, in spite of a stagnation in banana trade (FAO, 2000: 38).

[36] For example the alternative agricultural network consisting of 30 NGOs in the Thailand spread information and carry out other activities to strengthen the relationship between farmers and consumers (Lianchamroon 1994). The marketing support provided by Penang Organic Farming Club, and the farmers-consumers relations in that area in Malaysia is also notable in this regard (Ong, 1997).

In addition to the spread of information, certain activities such as the popularisation and the distribution of traditional varieties of seeds and other planting materials are of great importance. There could be a substantial role here of both farmers' networks and NGOs, as also of institutions such as the National Bureau of Plant Genetic Resources, which has huge germplasm collections that are no longer available in situ. Also forestry institutes and others with a mandate to preserve tree genetic diversity ex situ. This again becomes important due to the non-availability of such planting materials, in localities from which they have disappeared in the past due to several reasons. The spread of information on the potential use of some trees/plants survived in home gardens, such as medicinal plants is also useful in this regard

5. Conclusion and Plan of Action

The basic objective of this paper was to outline a viable strategy for the conservation of biodiversity in home gardens, through a systematic analysis of the factors that cause the erosion of this diversity. This became important in the context where almost all the existing studies of home gardens have not made any attempt to analyse farmers' decisions with regard to biodiversity so as to enable policy-making for influencing their decisions to facilitate its conservation. This paper made an attempt to conceptually analyse the factors that cause erosion of biodiversity in home gardens. Such factors are categorized as market failure, government failure and information failure.

Market failure arises out of the gap between the private and social benefits of conserving biodiversity. This is especially so in the case of home gardens, where the conservation has to depend ultimately on farmers' choice unlike in other resources such as forests. Thus the requirement of society to conserve more diversity in home gardens due to its potential uses, than what is conserved by the farmers based on their interests, has to be met through some form of subsidies (here the term, subsidy is used in a broad sense encompassing all the monetary and non-monetary support and compensation given to individual farmers by the society). This requires some understanding of what to be conserved through home gardens.

However, the popular feeling among some environmentalists that markets always emanate signals against the conservation of biodiversity is wrong. There are a number of factors that create a situation in which farmers find it 'profitable' to conserve a diverse farming system than a mono-crop cultivation. These include not only the growing demand for 'natural' products but also the complex interaction of commodity, labour and capital markets. It is seen in humid-tropical areas that the movement from farm based occupations to other non-agricultural occupations facilitates the sustenance of multi-tree systems rather than the intensive cultivation of mono-crops. However, this market-facilitated enhancement of biodiversity, may not be adequate to meet the social requirements of biodiversity, and hence the need for correcting market failure.

In addition to market failure, many policies adopted by the government are seemingly affecting the sustenance of diversity in home gardens. These include direct and indirect subsidies for planting, nurturing and marketing of specific crops and varieties. In some cases, such subsidies have led to even economic losses for the society, and have not been useful in meeting the social objectives for which they were designed. Even for socially useful purposes, the subsidies could have been in such way so as to avoid the 'side-effect' of unwantedly reducing the biodiversity in home gardens.

There are also problems due to lack of awareness and inadequate information that have led to the erosion of biodiversity in home gardens. The disappearance of a few varieties/crops, and the knowledge of their beneficial use from a locality, can aggravate this problem of information failure, and make it almost difficult or very costly to bring back these varieties and uses in future to the same location. Thus the creation of awareness, spread of information and the efforts to make traditional varieties available, etc., are important for the conservation of biodiversity in home gardens.

Based on the analysis and observations of this paper, the following plan of action is suggested for the conservation of biodiversity in home gardens:

a. Identify those highly diverse home gardens that exist in different parts of India: This can be done through the coordinated effort of agricultural researchers and NGOs.

b. Identify the key elements that warrant conservation in these set of home gardens: These key elements may include the availability of some species or their varieties, certain practices or knowledge, some structural parameters, or certain social or cultural features that influence the nature of home gardens

c. Constitute an `award' or `prize' system of rewarding highly diverse home gardens: These prizes or awards can be for the totality of the home garden and/or for the identified key elements depending on the requirement the locality.

d. Declare a few highly diverse home gardens as `natural heritage' sites: Some provision of resources for their sustenance can be instituted, and these can also be made to attract visitors.

e. Bring the attention of product makers, including biodiversity prospectors, to the diversity that exist in home gardens and facilitate the emergence of arrangements to share the benefits of such product development.

f. Regional networks for marketing `natural' products from home gardens can be formed with the initiative of NGOs. Explore ways of linking these regional networks with the other regional and international networks of organic products.

g. Evaluate the crop-based agricultural development policies and property right regimes on their potential impact on the sustenance of home gardens. Initiate steps to change these policies if these are not irreplaceable for other reasons.

h. Encourage the institutes having in-situ collection of traditional varieties and species to share with the farmers who are interested in enhancing the diversity of their home gardens.

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Summary and Plan of Action

This paper that aims at outlining a viable strategy for the conservation of biodiversity in home gardens identified three major reasons for the erosion of this biodiversity, namely market failure, government failure and information failure.

Market failure arises out of the gap between the private and social benefits of conserving biodiversity. This is especially so in the case of home gardens, where the conservation has to depend ultimately on farmers' choice unlike in other resources such as forests. Thus the requirement of society to conserve more diversity in home gardens due to its potential uses, than what is conserved by the farmers based on their interests, has to be met through some form of subsidies (here the term, subsidy is used in a broad sense encompassing all the monetary and non-monetary support and compensation given to individual farmers by the society). This requires some understanding of what to be conserved through home gardens.

In addition to this market failure, many policies adopted by the government are seemingly affecting the sustenance of diversity in home gardens. These include direct and indirect subsidies for planting, nurturing and marketing of specific crops and varieties. In some cases, such subsidies have led to even economic losses for the society, and have not been useful in meeting the social objectives for which they were designed. Even for socially useful purposes, the subsidies could have been in such way so as to avoid the 'side-effect' of reducing the biodiversity in home gardens.

There are also problems due to lack of awareness and inadequate information that have led to the erosion of biodiversity in home gardens. The disappearance of a few varieties/crops, and the knowledge of their beneficial use from a locality, can aggravate this problem of information failure, and make it almost difficult or very costly to bring back these varieties and uses in future to the same location. Thus the creation of awareness, spread of information and the efforts to make traditional varieties available, etc., are important for the conservation of biodiversity in home gardens.

Based on the analysis and observations of this paper, the following plan of action is suggested for the conservation of biodiversity in home gardens:

a. Identify those highly diverse home gardens that exist in different parts of India: This can be done through the coordinated effort of agricultural researchers and NGOs.

b. Identify the key elements that warrant conservation in these set of home gardens: These key elements may include the availability of some species or their varieties, certain practices or knowledge, some structural parameters, or certain social or cultural features that influence the nature of home gardens

c. Constitute an `award' or `prize' system of rewarding highly diverse home gardens: These prizes or awards can be for the totality of the home garden and/or for the identified key elements depending on the requirement the locality.

d. Declare a few highly diverse home gardens as `natural heritage' sites: Some provision of resources for their sustenance can be instituted, and these can also be made to attract visitors.

e. Bring the attention of product makers, including biodiversity prospectors, to the diversity that exist in home gardens and facilitate the emergence of arrangements to share the benefits of such product development.

f. Regional networks for marketing `natural' products from home gardens can be formed with the initiative of NGOs. Explore ways of linking these regional networks with the other regional and international networks of organic products.

g. Evaluate the crop-based agricultural development policies and property right regimes on their potential impact on the sustenance of home gardens. Initiate steps to change these policies if these are not irreplaceable for other reasons.

h. Encourage the institutes having in-situ collection of traditional varieties and species to share with the farmers who are interested in enhancing the diversity of their home gardens.

i. Encourage NGOs and others to propagate knowledge on the uses of traditional varieties such as herbal remedies.