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Living with weeds - a new paradigm

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ABSTRACT

Some people, particularly in developed countries, have strong negative attitudes towards weeds, and a tendency to label potentially useful plant resources as invasive 'aliens', which are to be controlled at any cost. This undesirable attitude ignores the considerable evidence of beneficial uses of weed species to many societies, over a long period of human history. The recent application of 'species-focused' weed risk assessments have contributed to the maligning of many plant taxa as 'invaders' in the public's mind, undermining their worth as biological resources. Some of the methods used in the blitz against weeds, including the excessive use of herbicides, have resulted in undesirable consequences, such as herbicide resistance, and negative impacts on biodiversity in farming landscapes. Weeds maintain the biological diversity of farming landscapes, providing food and shelter for a variety of animals. Insects, which pollinate crops, extensively use weeds as a source of nectar, when crops are not in flower. Weeds also attract crop pests; and there is evidence that pest populations in some crops are much lower in 'weedy fields' than in 'weed-free' crops. As many of our primary crops have 'weedy-relatives', the genes present in weeds appear crucial for future evolution of crops, particularly to confer 'hardiness' (ability to tolerate variable environmental conditions). Some weed species contribute to aesthetic pleasure, as part of 'wild nature', while others provide culinary delights for humans, and are important as food sources for both vertebrate and invertebrate animals. Many weeds with medicinal values continue to be used either as traditional 'herbal' remedies, or extracted for secondary metabolites. The colonising strengths of several species are being used in the remediation of water and terrestrial environments to scavenge soil pollutants. Globally, there is considerable interest in using the large biomass produced by these species as raw materials for countless household products, including bricks, paper and furniture; and as future bio-fuels.Therefore, within the field of weed science, a fresh look at weeds is essential. Perhaps, a new and bold paradigm should be 'co-existing' or 'living with weeds', recognising their intrinsic worth as part of biodiversity, and the many possible uses as bio-resources.

Key words: Beneficial effects of weeds, Colonising species, Utilization of weeds, Weeds as biological resources

Negative impacts of weeds are wellknown. Many weeds compete aggressively with crop plants, reducing yields and crop quality, and take the space of native bushlands or garden plants. Some can also taint milk, and others are poisonous to humans and domestic animals. Still others have attributes like thorns and spines, which cause physical injury. Some weeds may act as host plants for parasitic insects or diseases, while yet others can be parasitic on other plants. Through these direct or indirect effects, weeds often increase the cost of farming and decrease the value of agricultural land and produce. In some circumstances, they may even threaten the biodiversity of landscapes, national parks, conservation areas, aquatic habitat and waterbodies.

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In US agriculture, weeds cause a reduction of 12% in potential crop yields. In economic terms, this represents about US$ 33 billion loss in crop production annually, based on the crop potential value of all US crops of about US$ 267 billion/year (Pimentel *et al*. 2000). In Australia, the cost of weeds to Australia's primary industries in lost production and weed control exceeded Aus$ 4 billion per year (Sinden *et al*. 2005). In India, weeds cause about 30% losses in potential crop production, which is worth about US$ 90 billion/year in reduced crop yields (Pimentel *et al*. 2000). These are highly significant figures. Our dislike for weeds is also reflected in the global figures from agrochemical sales. Globally, we spent US$ 35.8 billion and $39.4 billion in 2006 and 2007, respectively, on agrochemicals, of which 40% ($14.3 billion) and 39% ($ 15.5 billion), respectively, were for herbicides

(Grube *et al.* 2007). It was estimated that herbicides of worth ` 11,600 crores or 116 billions will be required annually to control *Parthenium hysterophortus* infested in an area of about 35 million hactares land in India (Sushilkumar and Varsheny 2010).

Given the negative impacts that weeds may have on agriculture, environment, and to human societies in general, it is essential to understand these plants better. Some plant species become weeds because they are competitive, adaptable, highly fecund, and are capable of exploiting naturally disturbed or man-made habitats. As humans manipulate our surroundings to fulfil our needs, we provide an environment suitable for certain plant species, which may thrive under those circumstances. They are not ecologically 'plants out of place', as some older definitions have suggested. In fact, in an ecological sense, the opposite is true. Weeds are just opportunistic species or '*pioneers of secondary succession*' (Bunting 1960), that are well adapted to grow in locations where disturbances have opened up space (Grime 1979).

In many ways, humans may also be regarded as 'weeds', because we are highly adept at disturbing and colonising landscapes, as well as perpetuating our species. As Harlan and de Wet (1965) wrote: *"…The word weed is taken to mean a species or race, which is adapted to conditions of human disturbance. By this definition…..animals such as the English sparrow, the starling, the "statuary" pigeon, the house mouse, Drosophila melanogaster, and others are especially fitted to environments provided by human disturbance. Indeed, perhaps no species thrives under human disturbance more than Homo sapiens himself. In this ecological sense, man is a weed…"*

A set of common biological characteristics allows weeds to colonise disturbed habitats, to form extensive populations, and often, to dominate landscapes. These include high fecundity (numbers of individuals produced), the ability to germinate and grow rapidly, and tolerance of a wide range of environmental conditions (Baker 1965). However, a species may initially colonise, and then become an invader of landscapes only if a chance combination of circumstances makes its attributes particularly advantageous to its growth and survival (Naylor and Lutman 2002). In many cases, this opportunity arises because of lack of natural enemies, specific parasites or herbivores, which gives them an advantage over crops and native flora. Various features of the plants themselves (such as phenotypic plasticity, and ability to produce chemical defences to deter herbivores) would assist the colonisation process. However, in the right place, many of these extraordinary plants can provide benefits that can be exploited for human welfare. If evolutionary success means continuing a genetic line over time, and in terms of the Darwinian concept of the struggle for existence, many weeds must rate amongst the most successful plants that have evolved (Auld 2004).

A recent trend has been to refer to the growth of weeds in disturbed habitats as an 'invasion' of natural or man-made habitat by some introduced 'aliens'. This rather xenophobic view, and the resultant 'War on Invasives' is full of 'scientific' theories, scaremongering and far-reaching policies, based on highly subjective opinions of 'good' plants verses 'bad' plants. The effect has been that governments, various corporations, organizations and the pubic spend billions of dollars trying to control the 'fugitive' plants! This war was created by the belief that a new, 'exotic' plant species entering a 'native' ecosystem is always harmful to the surrounding inhabitants. Several major publications have highlighted the issue of significant negative impacts of invasive specieson the local environment (Vitousek *et al*. 1996, Mack and D'Antonio 1998, Groves and Willis 1999, Richardson *et al*. 2000, Groves *et al.* 2005). Whilst this may be true in some cases, the overuse of herbicides, destructive land clearing and indiscriminate weed removal policies and practices, and a hate mentality that maligns species do more damage to native habitats and ecosystems. Over-reacting on this issue with badly planned and indiscriminate weed control actions also divert vast resources that could be better spent on more useful measures, such as preventing land clearing and habitat destruction, preservation of biological diversity, studying plant medicines, renewable resources, and educating the public on the values of weeds as part of nature.

It is clear that weeds were here before us; and will be here after us! Therefore, instead of engaging in an 'unwinnable war', a fresh look at the potential of 'co-existing' with weeds and using them as resources is overdue, given their biodiversity and environmental values, and many possibilities of utilization that can be demonstrated (Jordan and Vatovec 2004, Kim *et al*. 2007, Varshney and Sushilkumar 2009). In many cases, the focus of Weed Research is on managing problematic species in specific situations, rather than on their well-known beneficial impacts in agro-ecosystems, or potential for utilization. However, if farmers and land managers can be led to appreciate the extraordinary strengths of colonising taxa, this will allow a better integration of these species into our economies and overall farm productivity. Improved understanding of the causes of biological invasions will also reduce the current confusion and negative attitudes towards invasive species. The purpose of this paper is to discuss the above viewpoints and argue that: *not all weedy taxa are bad all the time, just because they may interfere, under certain circumstances, with human interests*.

Are all weeds really bad?

Ralph Waldo Emerson, the American Naturalist, had the right idea. His 1873 quote: "*…What is a weed? A weed is a plant whose virtues have not yet been discovered*" expressed a positive view of weeds and their intrinsic worth (virtues), as opposed to negative impacts (Emerson 1873). In Jack Harlan's opinion(1975): "*..Weeds are adapted to habitats disturbed by man. They may be useful in some respects and harmful in others. They may be useful to some people and hated and despised by others...*"Ehrenfried Pfeiffer (1970) elegantly mused as follows: "*…Weeds are only weeds from our egotistical point of view, because they grow where we do not want them. In nature, however, they play an important and interesting role. They resist conditions, which cultivated plants cannot resist, such as drought, acidity of soil, lack of humus and mineral deficiencies, as well as a one-sidedness of minerals. They represent human beings' failure to master the soil, and they grow abundantly wherever people have made mistakes – they simply indicate our errors and nature's corrections...*"

These well-known, sympathetic views of weeds provide the basis for a re-appraisal of our attitudes. *Are weeds really bad?* The answer may depend on an individual's perceptions, but for ecologically-minded Weed Scientists, interested in creating a food-secure society in productive, but sustainable and ecologically-healthy landscapes, it must be a resounding: *No*. Taken individually by species, or collectively as a group - weeds are the most fascinating and extraordinary plants in the world. They are top-notch, skilled survivors, often thriving in inhospitable environments and extreme conditions, where otherspecies would fail. Much of the time, they appear to mock our unsuccessful attempts to eradicate them! They can teach us – animals -how to survive and make the best of any situation. As humans face significant uncertainty in a relatively unstable future climate, brought about by our own actions (and inactions), the strategies for survival demonstrated by weeds would be great lessons to learn.

Weeds do not ask for much; they may take some of the earth's resources for their growth and survival; they may also make humans toil a bit more, farmers in particular, but they give back a lot more than we realise (Pfeiffer 1970). In a rapidly changing world, with limited resources and a burgeoning human population, weeds tell us how to share those limited resources, *differentiate our ecological niches*, and co-exist. If we have an enlightened attitude towards weeds and understand them better and apply those ecological principles, it would do well for the survival of our species.

For all other animals, except humans, weeds are undoubtedly a great resource. Most animals cannot be choosy, and they are generally adept at exploiting any resource available for food and shelter. Nearly all insects, fish, birds and foraging herbivorous animals use colonising plants as resources. Birds, bees, ants and other insects derive sugary food from the flowers and fruits of species, such as Lantana (*Lantana camara* L.), consideredan obnoxious pest (Gosper and Vivian-Smith 2006). Similarly, bumblebees, the great pollinator of field crops, rely heavily on weeds for sugary nectar. Macro invertebrates and small fish, living in our streams, thrive on food in the root zones of large macrophytes, such as *Typha angustifolia* L. and *Phragmites australis* (Cav.) Trin. ex Steud (common reed), which are also often regarded as problematic aquatic weeds. Such multi-faceted interactions in the Natural World are quite fascinating, and should be much more meaningful for Weed Scientists to study than spending countless hours researching only the harmful effects of weeds and how to control them.

Weeds and crops are close relatives

"*…There are weed races of most of our field crops and these interact genetically with cultivated races as well as truly wild races. This interaction probably results ultimately in better crops and more persistent weeds. Although some weeds have evolved elegant adaptations under the influence of man, many had weedy tendencies before man existed. Weeds are products of organic evolution; they exist in intermediate states and conditions. They are also genetically labile and phenotypically plastic*" (Harlan 1975).

The interaction between humans and weeds has been going on for millennia, and probably date back to domestication of plants about 12,000 years before present. As suggested by Jack Harlan, firstly in 1975 (quote above), many species that became crop plants have 'weedy' relatives, and several have actually evolved from weeds. Therein lays our first and the most significant interaction with weeds: based on plenty of scientific evidence, almost all of our major food crops originated from relatives who might be considered 'undesirables' in today's context! The co-evolution between weeds and crops is an on-going process (Harlan 1965, 1975), and genetic exchanges between related species are part of natural evolution.The accepted view (Baker 1974, 1991) is that many weeds of today are as old as agriculture itself and have substantially evolved with adaptations and characteristics that enable them to grow, flourish, invade, and dominate cropping fields, which arehuman-disturbed environments. Once evolved in agricultural habitat, the same attributes of survival, spread, fast growth and persistence, allowed many weeds to exploit other relatively undisturbed, more natural systems, where vacancies and opportunities existed.

There is also general consensus that most cosmopolitan weeds across the globe originated in the agricultural fields of one kind or another. These plant species represent a significant component of the agro-ecosystem, resulting from the continuous selection pressure imposed on them by man, his tools, agricultural practices, and methods of weed control. 'Agrestals' or, wild plants growing within or adjacent to agricultural fields, have long been exposed to both natural and human breeding and selection systems that enabled them to survive and insure their future generations. They have also proved to be excellent invaders into human-made habitats, taking advantage of all measures that man imposed to eliminate or to keep them fully under his control.

Weeds are much maligned, but not all weeds are 'bad' all the time

Weeds are the most maligned group of plants in the world, certainly in developed countries. The Weed Science literature is full of books, review papers and reports that highlight negative aspects of weeds in cropping and non-agricultural landscapes. The recent species-focused 'Weed Risk Assessments' have created a pervasive myth: an impression that most introduced species are undesirable in any new habitat, and are likely to be problematic. Even if we understand the imprecise idea of '*border protection*' with regard to the deliberate and unnecessary introductions of potentially invasive species from one part of the globe to another, isn't it another human folly to assign a '*guilty until proven otherwise*' tag to many useful plants?

The term '*invasive plants*' refers to '*any naturalised species that has a capacity to expand their geographic range and spread in the area to which it has been introduced*, and have detrimental impacts (Richardson *et al*. 2000). They are, therefore, *a subset of non-native species that cross a threshold for disproportionate negative impacts in an ecosystem*, and this distinction is considered vital. The definition recognises that: (a) Introduced species could become 'naturalised' in areas where they did not exist before, and 'invade' or gain geographical territory, with or without human assistance; and (b) Such species often cause harm to the environment, economy, or human health. Somewhat implicit in the definition is the view that *not all exotics are invasive, but all invasives are exotic*.

It is important to note that most exotic species, which may be naturalized and reproduce self-sustainably, represent a small fraction of the community in which they are introduced and typically have negligible influence on plant communities they inhabit. On the other hand, a few species, which have high rates of population growth and spread, may become dominant members of plant communities; have a negative influence on native species; and may alter the functioning of ecosystems. Good examples are: *Lantana* in India and Australia; Mesquite (*Prosopsis* spp.) and Prickly Acacia (*Acacia nilotica* (L.) Delile) in Australia. Many recent publications have highlighted the dangers posed by 'environmental weeds' and 'sleeper weeds', which may impact adversely on natural landscapes (Mack and D'Antonio 1998, Richardson *et al.* 2000, Williams and West 2000, Groves *et al*. 2005). Environmental weeds are usually non-native, but naturalised plants, which could have a negative impact on native species diversity. It should be noted that some native plant species that are invasive beyond their indigenous range can also become environmental weeds; an example is: Golden Wreath Wattle (*Acacia saligna* (Labill.) H.L. Wendl.), indigenous to Western Australia, but is naturalised and considered a major problem in the Eastern States of Australia. 'Sleeper weeds' are a sub-group of plants that arrive at a region, naturalise (*i.e.* establish and self-reproduce), and remain localized for a long period, usually greater than about 50 years, before they become seriously invasive (Groves 1999). The single species focused risk assessments' mind-set has created a dubious list of maligned species, which is already quite impressive and is dangerously growing longer.

'Weediness' is in the eye of the beholder

After much debate in the 1980s, the Weed Science Society of America (WSSA) defined a weed as: '*a plant growing where it is not desired*'. The European Weed Science Society (EWSS) extended this to include: '*any plant or vegetation, excluding fungi, interfering with the objectives or requirements of people*'. The Australian definitions have a strong slant towards the European version, *i.e.* '*a weed is a species that adversely affects biodiversity, the economy or society*' (Groves *et al.* 2005) or '*a weed is a plant, which has, or has the potential to have, a detrimental effect on economic, conservation, or social values in Australia*' (ARMCANZ 1999). These definitions are only partially true; by effectively removing man's culpability, they miss the essential point that *weeds are a symptom of a man-made crisis, but not the cause of it.*

However, even plants with strong colonising attributes are of value in various situations, at different times, or to different people (Chandrasena 2007). Therefore, developing countries will do well to broaden the common definition to capture the idea that weeds present problems to some people, and certainly not to all people; at all times or at all places. In that regard, Kloot's (1987) definition from Australia that a weed, '*is a plant that may interfere with human activity in one way or another and, thus, has come to be regarded negatively by at least part of the society*' is a reasonable one to consider.

Five decades ago, Bunting (1960) had already clarified that '…*weeds are pioneers of secondary succession, of which the weedy arable field is a special case*…' and they specialize in the occupation of ground stripped of plants by landslides, floods, fires, or by man's activities. Largely agreeing with Bunting, Baker (1965) defined a weed as: '…*a plant if, in any specified geographical area, its populations grow entirely or predominantly in situations markedly disturbed by man, (without, of course, being a deliberately cultivated plant)*…' Zimdahl (1999) favoured the view that weeds are: '…*those plants that are successful in disturbed environments, are fast growing, and, are often, but not always herbaceous*…' These well respected definitions emphasize the human connection and man's own role in creating disturbed habitats. Bunting (1960) also said, '…*an essential feature of all of man's activities, in agriculture or otherwise, is the production of open, or at least disturbed, habitats*…' Downplaying man's role in creating much of the disturbance to which colonising plants naturally respond has led to misconceptions, and, over time, to the hardened attitude towards 'weedy' taxa. Most people, growers, farmers, biologists, and even politicians will agree that weeds can be are useful resources, at various times. This word 'weed' - *an epithet of human invention and a dubious 'cultural construct'* - has caused so much confusion within the field of Weed Science. In the world of plants, it simply does not exist. As Plato said in 300 BC - '…*beauty is in the eyes of the beholder*…'; 'Weediness' is definitely in the eyes of the beholder; in my view, much of the time this human perception is subjective and flawed.

Weeds or useful plants - a matter of opinion and circumstances

Grice and Brown (1996) highlighted the dilemma of labelling a weed in relation to managing Australian rangelands. From a conservation perspective, a species may be called a weed because it is non-native; from a land use perspective, a native or an introduced species may be labelled a weed because it is toxic to livestock, or reduces agricultural productivity. From an ecological point of view, a species may be called a weed, because it changes the structure of a plant community, or modifies some attribute of an ecosystem, such as the local hydrology.The same species may be identified in another situation by different users, as a useful plant. There are many examples, which demonstrate the tenuous nature of the human judgement on the virtues of a species, whether it is a weed or a useful plant. Clearly, *this is a matter of opinion, largely based on human needs, wants, and perceptions, at a particular time, place, or circumstances*. Such opinion is highly subjective, easily swayed by the needs of a situation, short-term gains, and profit motivation, and there is room for significant error.

Until about the 1970s, weed issues were discussed only from the perspective that they were problems to crop production. In subsequent decades, attention turned to weeds as environmental fugitives affecting our landscapes. Weeds are now projected as major 'villains and thugs', who affect all aspects of our daily lives! Much energy and resources are spent fighting them. However, *is the problem really weeds? Or is it our perception of them*? Weed occurrence is inevitable, because man's activities will continue to disturb environments, and movement of people across continents will exacerbate introductions into new areas. There is no simple remedy for the weed problems in their many manifestations. Prevention of introduction of species to where they did not exist before is strategically the best approach. Sometimes it may be possible to eradicate a relatively small population of a potentially invasive species from a given area, but more often than not, eradication is a flawed approach in most ecosystems. This is because of secondary effects of eradication of a target species (i.e. creating more disturbances, whether by the use of herbicides or physical removal), to which other species will respond. In many ecosystems, there are likely to be compensatory increases of other colonising species, making use of new opportunities.

Therefore, whilst continuing to study the reasons why colonising species sometimes come to dominate landscapes, the best management strategy would be to use several control tactics in an integrated manner, but with heightened emphasis on prevention. Management approaches must attempt to prevent new introductions to disturbed areas, rehabilitate disturbed areas as soon as possible, and to minimise the undesirable impacts where conflicts exists between man and weeds. However, a proper ecological understanding, and a balanced view of economic implications are essential for this. taxa.

Beneficial effects of weeds

The negative connotations associated with colonising species are of such magnitude that for some people it may seem paradoxical that weeds are actually beneficial. Prior to launching major offensives against weeds, all Weed Scientists and Weed Managers should recognise the positive and redeeming values of weeds and properties of these plant species that are highly beneficial to human societies. This recognition requires a conceptual change in direction, and an *acceptance* of the fact that *weeds are beneficial in the right place, under the right circumstances*. The primary objective of this essay is therefore to highlight some of the beneficial effects of these much demonised, wrongly accused group of plants, and highlight the possibilities of human societies 'living with weeds'. Several other publications have already emphasized various beneficial effects of weeds (Altieri 1988 1995, 1999, Marshall 2001 and references therein), and these support why a conceptual change is necessary. Some of the positive aspects of weeds have been extensively canvassed in a monograph, edited by Kim *et al.* (2007), and more recently, in a National Consultation on 'Weed Utilization' held in October 2009 in India (Varshney and Sushilkumar 2009, and references therein).

Weeds as components of biodiversity and wild nature: Weeds are beneficial not just because of the potential utilization value as various raw materials; or as food and shelter for humans and animals, but also for their innate abilities and ecological and biological roles in natural and man-made ecosystems(Marshall 2001, Marshall *et al.* 2003, Storkey and Westbury 2007, Kim *et al.* 2007). There is also a moral and ethical imperative to value weeds as part of 'wild nature', which is under threat, as a result of burgeoning human populations in several countries, and over development in the creation of 'humanised space'. In many situations, weeds are not the problem; the real culprit is man and his limitless greed, and over-exploitation of resources that has placed the sustainability of the earth's ecosystems in jeopardy.

The term 'biodiversity' describes the biological diversity; or assemblages of organisms that have evolved together to exploit the resources of an environment, in ways that maximises the cycling of energy and nutrients within that area: *i.e.* an 'ecosystem'. By their nature, ecosystems are dynamic and they change in response, both to environmental changes and due to the adaptive evolution of their constituent species. As primary producers,plant sare key components of such systems, with different species occupying various ecological niches, filling a variety of roles (Jordan and Vatovec 2004, Kim *et al.* 2007). Colonising plants are important in many ecosystems, primarily because they are more effective at exploiting available resources and would fill many niches that slow-growing plants are not able to occupy; for the provision of various ecosystem services; and also as primary producers. However, in many instances, weeds may only be a relatively small fraction of the total biodiversity of an ecosystem, although they are roundly condemned for a variety of negative impacts.

Agroecological benefits of weeds: Biodiversity in Agroecosystems responds to changes in agricultural management.Many studies in Britain and Western Europe have clearly identified serious declines in the populations and ranges of birds, and declines in populations of mammals, insects, soil organisms, and plants, associated with arable lands (Marshall 2001, 2002, Marshall *et al.* 2003). As a result, the current European Union (EU) policy is to encourage farmland biodiversity through less intensive farming, which is to be achieved by: (a) Reducing the area cultivated; and (b) Less intensive management. Weeds are increasingly recognised as valuable *'indicators of biodiversity'*, because if they are present, they would provide food and shelter for a wide variety of animal species, increasing the abundance of organisms inhabiting agricultural landscapes. Given the imperatives of *sustainability*, agriculture in some countries are changing, accepting certain levels of weeds adjacent to field crops, often along boundaries, or as wind-breaks (Marshall 2001). Weedy strips are either planted, or allowed to flourish, encouraging a greater abundance of farmland insects and birds. Weeds can draw pests away from crops. Others can provide habitat and floral resources for natural enemies that control pests, for pollinator species that provide crop pollination (Altieri 1988, 1995, 1999, Marshall 2001, 2002, Marshall *et al.* 2003).

A principle in integrated pest management (IPM) is to broadly increase the biodiversity in agroecosystems, so that there will be increased interactions between organisms (*i.e.* herbivores, predators, detrivores, and decomposers). The premise is increased interactions would lead to efficient nutrient transformations, and energy recycling through ecosystems, and self-regulation of populations. The role of colonising species in such key roles needs to be better understood not just within the agroecosystems, but also in farming or non-farming landscapes, so that they can be effectively integrated into sustainable agriculture and healthy environments.

In both agricultural and non-agricultural landscapes, weed cover reduces soil erosion; conserves soil moisture; reduces the loss of nutrients from soil, as well as add nutrients and organic matter into soils of poor quality. Moreover, there is increasing evidence of positive impacts of weeds on soil structure, and the functioning of beneficial soil organisms, including soil microbes, involved in nutrient cycling. Fast-growing, colonising plants are crucial as 'living mulches' and cover crops for the conservation of soil, water and organic matter (Altieri 1995). Many sterile annual grasses (*Lolium* spp., *Poa* spp., *Echinochloa* spp.) are deliberately sown in western countries, as cover-crops, to protect bare soil on road verges, and rehabilitate 'disturbed' areas. As pioneers of secondary succession, these weeds grow fast and proliferate on soils with low fertility, and many decompose readily, adding organic matter and nutrients to soil. Some examples are fast growing legume vines, such as *Pueraria* spp., *Stylosanthes* spp.,*Calapogonium mucunoides* and *Macroptilium artropurpureum*. These colonisers are particularly important as ground cover-crops in tropical plantations and orchards. In other situations, they serve as forage for animals and are also used for pasture improvement. Sometimes, their rampant growth may require management, so as to derive benefits, and not add to problems. However, the potential for using such species with colonising attributes in sustainable agriculture cannot be disputed.

The search for self-sustaining, low-input, diversified, and energy-efficient agricultural systems is now a major worldwide concern. A key strategy in sustainable agriculture is to restore both the structural heterogeneity at the different spatial scales of field, farm, and landscape; and the functional biodiversity of the landscapes (Altieri 1995, 1999). This can be achieved in time through age-old practices like crop rotations and sequences, and in space in the form of cover crops, inter-cropping, agroforestry, and crop/livestock mixtures. Plants with colonising abilities need to be recognized as an integral part of such conservation farming approaches. Weedy species add much to biotic interactions by way of their highly developed chemical defenses, and they perform a variety of ecosystem services. Creation of appropriate biologically diverse cropping and non-cropping landscapes is likely to result in: (a) Increased pest regulation through restoration of natural control of insect pests, nematodes and pathogenic fungi, bacteria and viruses; and (b) Optimal nutrient recycling, by activating soil biota. All of these factors should lead to more sustainable farms and yields, better energy conservation, and less dependence on external inputs. However, the challenge is the extensive adoption of such approaches, and success will depend on the demonstration of the synergies of biodiversity conservation and the economic profitability of farming.

Weeds as repositories of valuable genes for crops: Genetic diversity within populations is the basis of evolution; biodiversity in any given area encompasses the genetic diversity of organisms. As apparent in many examples of weeds and their crop relatives (see Harlan 1965, 1975), the gene pool and genetic diversity of weeds appears crucial in the future evolution of crops. This, I suggest, is another crucial reason for accepting the idea of 'living with weeds'. Weed populations, exhibiting the widest diversity of heritable traits, would be far better equipped to cope with and survive any future environmental changes. Crops, with 'weedy-relatives' would surely benefit from the exchange of genes. The best examples of plant families and genera that demonstrate the closeness of crops and wild species come from the Poaceae (grasses) with all of our major cereals having evolved from wild grass relatives. Other families, such as Solanaceae (nightshades family), Brassicaceae (mustard family), and Cucurbitaceae (gourd gamily) also have numerous examples of wilder, weedy relatives, which are also edible, and domesticated plants that have been cultivated over millennia.

Other beneficial uses and impacts of weeds: Beyond biodiversity values, agro-ecological values and being part of wild nature, the colonising power of plants has been harnessed extensively by societies for a variety of uses, over millennia. The beneficial uses include exploitation as food, medicines, raw materials for industry, animal fodder, and for improvement of water resources and landscape health. There is much to be gained by re-iterating these values, as discussed below, to demonstrate that 'living with weeds' is not incongruous with sustainable agriculture, healthy environments and lifestyles, which are attuned with nature.

Edible weeds: Many weeds are edible, serving as traditional food every day for people all over the world, as discussed in many publications (Holm *et al.* 1977, Duke 1992, Lee *et al.* 2007, Abeysekera and Herath 2007, Bakar 2007, Maneechote 2007, Morita 2007, Varshney and Sushilkumar 2009). More importantly, some are true culinary delights in Asian cooking. Amongthe three topexamples of edible weeds are: *Alternanthera sessilis* (L.) R. Br. (Mukunu-wenna); *Centella asiatica* (L.) Urb. (Asian Pennywort), and *Ipomoea aquatica* Forssk. (Kang Kung) (Chandrasena 2007). Leaves and young shoots are the most commonly used parts of the weeds. In the Asian-Pacific region, more than 150 weed species are considered edible (Kim *et al.* 2007). These include various *Amaranthus* spp., *Taraxacum officinale* Webb. (Dandelion), *Rorippa palustris* (L.) Besser (Water Cress), and *Portulaca oleracea* L. (Purslane).

Medicinal weeds: Weed species form a substantially higher proportion of source plants in pharmacopoeias than would be expected from their proportion in the general flora (Stepp 2004, Stepp and Moerman 2001, Voeks 2004). The possible reasons are related to the life cycle of most (annual) weeds being ephemeral, successional, or *r*-selected species. The opportunistic, short-lived species appear to rely heavily on qualitative toxic chemical defensesto deter herbivores, rather than quantitative compounds (Coley *et al.* 1985). These are secondary metabolites, which accumulate on leaves, shoots, flowers and fruits. They are glycosides, alkaloids, and terpenoids, which are all low molecular weight, often toxic at small doses, and highly biologically active. As a result, a large variety of weeds are used in traditional medicine and pharmaceutical industry as sources of therapeutic compounds. Many have healing effects, which include diuretic, choleretic, anti-inflammatory, anti-oxidative, anti-carcinogenic, analgesic, anti-hyperglycemic, anti-coagulatory and pre-biotic effects, and are used in the treatment of a wide variety of diseases. Among the best examples of weeds commercially important in western medicine are: *Digitalis purpurea* L. (Foxglove) from which digitalin, a group of cardiac-active glycosides is extracted;and *Catharanthus roseus* (L.) G.Don (Madagascar Periwinkle) from which an anti-cancer alkaloid - vincistrine, is extracted. The lists compiled by Bakar (2007), Abeysekera and Herath (2007), Maneechote (2007) and others, demonstratethe medicinal values of a large number of weed species, commonly usedin the Asian-Pacific region in traditional medicine, including Ayurveda and Chinese medicine.

Weeds as fodder for animals: In terms of quantities used, perhaps this category is important, although unremarkable. Many fast-growing species, annuals and perennials, including the previously mentioned legumes and grasses, which produce abundant biomass, provide the fodder required for rearing of animals, such as cattle, goats, pigs, sheep and even horses, ducks and geese. The aquatic weed, *Eichhornia crassipes* (Mart.) Solms (Water hyacinth) is a good example of a strong coloniser, which provides nutritious fodder (Kim *et al.* 2007, and references therein). There is also evidence that some species, deliberately introduced from one region to another as fodder crops, have subsequently become major invaders, requiring costly management.Two examples are *Pennisetum polystachyon* (L.) Schult. (Mission Grass); and *Andropogon gayanus* Kunth (Gamba grass), both introduced as fodder in Australia during 1940s and are currently spreading fast in Northern Australia.

Weedy residues as compost and mulches: The biomass of almost any weed can be composted, as most breakdown quickly; these may not serve as good mulches. On the other hand,biomass of some weeds, which breakdown slower, can be useful mulches. The large sized grasses, *Panicum maximum* Jacq. (Guinea grass), *Imperata cylindrica* (L.) Beauv. (cogon grass); *Urochloa mutica* (Forssk.) T.Q. Nguyen (para grass); and some of the fast-growing legumes, mentioned previously, are good examples. There is also significant interest in converting large amounts of weed biomass into valuable, nutrient-concentrated, odour free compost using worms (vermi composting). Many studies have demonstrated the benefits of harvesting even strong weeds, such as water hyacinth (Gupta *et al.* 2007, Gunnarsson and Peterson 2007) and *Parthenium hysterophorus* L. (Yadav and Garg 2010, Varshney and Sushilkumar 2009 and references therein) for composting, mulching and fodder.

Weeds as raw materials for thatching, weaving and other products: A large variety of weeds (dried and/ or flattened) provide traditional material forroofing and thatching of for rural dwellings, and also as raw materials that can be woven into household products, such as baskets and mats (Kim *et al.* 2007). Sedges: *Eleocharis sphacelata* R.Br., *Eleocharis dulcis* (Burm.f.) Trin ex Hensch., *Schoenoplectus* spp., *Cyperus papyrus* L., as well as *Typha* spp. and grasses, such as *Phragmites australis* (common reed) (Kiviat and Hamilton 2001) are the best examples of this category. The dried stalks of Water hyacinth are also popular for decorative weaving, for a variety of products with global appeal, including furniture (Kim *et al.* 2007 and references therein).

Weeds as raw materials for paper-making and other industrial products: A large variety of colonising species, particularly grasses, are suitable for extraction of high quality lingo-cellulose fibre and other materials. Examples are: *Spartina alternifolia* Loisel. (Cord Grass), *Erianthusarun dinaceus* (Retz.) Jeswiet (wild sugarcane), *Saccharum arundinaceum* Retz. (Hardy Sugarcane), *Saccharum spontaneum* L. (kans grass), *Phragmites australis* Steud. (common reed), and *Miscanthus sacchariflorus* (Maxim.) Hack. (amur silver grass). In addition, the stems of *Chromolaena odorata* (L.) King and H.E. Robbins. (siam weed) and *Ageratum aadenophora* (Spreng.) King and H.E. Robbins. (crofton weed), which contain large amounts of cellulose, are also used for fibre board manufacture in China (Kim *et al.* 2007). The large biomass produced by water hyacinth is also popular as raw material for paper and pulp industry in several countries in the Asia-Pacific region.

Aquatic weeds: Many aquatic weeds provide natural ecosystem services, such as water purification and aquatic habitat improvement in wetlands and streams, through nutrient accumulations and transformations. The same functions can be exploited for biological removal of pollutants from water, including nutrients and other contaminants. The use of water hyacinth in wastewater treatment systems has been well-established for over 40 years in several countries, including USA, China, India, and others (Vietmeyer 1975, Tiwari *et al*. 2007). Other examples of aquatic weeds that have been used in pollution removal include: *Typha* spp. (Taylor and Crowder 1983), *Phragmites australis, Bolboschoenus fluviatilis* (Torr.) Soják; *Schoenoplectus* spp., *Cyperus papyrus* L. (papyrus), and several other species of the sedge family (Cyperaceae).

Use of colonising species in phytoremediation of damaged ecosystems: Soils frequently receive a wide range of contaminants from industrial activities, sewage sludge disposal, metal processing, and energy production, and in many cases, remediation is both expensive and intrusive to ecosystems. Phytoremediation is the use of plants and plant processes to remove, degrade, or render harmless hazardous materials, such as nonvolatile hydrocarbons and immobile inorganic matter, including heavy metals, present in the soil or groundwater. The attributes of 'pioneering' species - fast growth and biomass production, wide tolerance of environmental stresses, and capacity to maintain high population densities, make them particularly attractive for use in phytoremediation of contaminated sites, mine-site rehabilitation and stabilisation of roadsides. For instance, Wang and Liu (2002) demonstrated the strong tendency for uptake and hyper accumulation of Cu, Zn, and Chromium (Cr) in heavy metal polluted environments by Water hyacinth, *Amaranthus retroflexus* L. (red root Amaranth), and *Silene vulgaris* (Moench) Garcke (maiden's tears). In a similar study, Wei and Zhou (2004) showed that Dandelion, Nightshade (*Solanum nigrum* L.) and *Conyza canadensis* (L.) Cronq. (Canadian horseweed) strongly tolerated single Cd or Cd-Pb-Cu-Zn combined pollution and exhibited characteristics of hyper-accumulators. Wu *et al.* (2005) also demonstrated the possibilities of using mixtures of weed species to eliminate Pb and other heavy metals from contaminated soils. Numerous other examples are discussed in Kim *et al*. (2007) and references therein.

Weeds as raw material for bio-fuels: Given the large biomass that colonising species can produce, there are significant environmental benefits in utilizing this biomass directly for burning as fuel (primary biofuels), or used as raw material for fermenting to produce bio-diesel, ethanol and methane (secondary biofuels). The possibilities have been demonstrated in China, India, USA and other countries. Examples are *Jatropha curcas* L., *Thlapsi arvense* L., *Arundo donax* L. (giant reed) and others. There is also considerable interest in using the biomass of shrub weeds and medium-sized trees, which have colonised large areas as biofuels. Water hyacinth continues to be of considerable interest, for the combined uses of both phytoremediation of polluted water, and fermentation to produce biogas (Singhal and Rai 2003).

Miscellaneous uses of weeds: A wide variety of colonising plants are used in landscaping; stabilization of slopes and banks and roadsides. Others are important as ornamental plants, handicrafts, and for building human shelters (bricks and roof thatching), as well as for green roofs (Lee *et al*. 2007, and references therein). In addition, several weeds are important as sources of natural, plant-based dyes, and many yield strong allelochemicals, which may be used as biological insecticides (Minggen 2007, Sondhia and Varshney 2009). Some provide useful ingredients of cosmetic products, such as soaps, perfumes, creams and hair oils.

The way forward

Weed Science, as a discipline, has undergone several changes in the past 50 years or so. This essay supports a conceptual change towards 'living with weeds' as another change that might have to be made in the efforts to preserve our environment for the benefit of both the present and future human societies. This view has been canvassed before (Altieri 1988, 1995, Jordan and Vatovec 2004, Kim *et al*. 2007), and needs to be part of a wider discourse within the field of weed science.

Understanding human culpability for promoting weed abundance: Firstly, let us be clear about man's culpability with regard to weeds. It would not be too imprecise to say human 'create' weeds: we certainly create lists and label them as 'unwanted' from our perspectives; we lay the land bare of plant cover with excessive clearing, disturbing the environment, 'creating' niches that colonising species take up; we arrest ecologically succession by turning vast swathes of land into cropping fields, although more than 50% of our species go to bed hungry each night; and we deliberately introduce organisms from one location to another for profit! Need any more be said about human culpability?

It is important for weed scientists to recognise that the aim of mechanized, large-scale, modern agriculture, as opposed to subsistence agriculture, is to export nutrients and energy from an area. Therefore, there is a natural antithesis between agriculture and conservation of biodiversity - we can never completely reconcile the two, but can we minimise the conflict? With mechanized agriculture and cropping, practiced on the scale that we are witnessing, combined with deforestation and land clearing, *humans present the greatest threat to nature, wilderness and biodiversity*, of which both people and colonising species are constituent parts. This message needs to be part of the discourse between weed scientists, ecologists, and the public, so that we may aspire to achieve a better balance between human greed, genuine development aspirations of nations, and global biodiversity. There are strong moral, aesthetic, social and economic reasons for protecting biodiversity. As Marshall (2001) pointed out: "*a culture, which encourages respect for nature and wildlife is preferable to one that does not*".

It has been argued strongly in numerous publications that colonising species threaten biodiversity. However, it should be evident that they also provide benefits that are not yet fully understood (Marshall 2002, Marshall *et al*. 2003). A key message from Agroecology (Altieri 1988, 1995, 1999) is that, if correctly assembled in time and space, biological diversity, including weeds, is capable of repairing landscapes, sponsoring soil fertility, protecting crops, and increasing productivity. Moreover, the evidence available supports the view that given the opportunity, colonising species will be at the forefront of remediation of damaged ecosystems and rehabilitation of land that had once supported large forests.

Will there be a change in attitude?: The hardened attitude towards weeds in developed countries is largely related to the profits that can be made by individual landholders through farming. Many farmers resist change because of personal learning experiences and property-related economic factors. Shifting the emphasis of weeds from totally undesirable to useful resources requires strong campaigning. This attitude change may come with time, but this can be hastened by economic incentives to manage biodiversity within farmlands, and landscapes, as has been done in EU countries. It can also be hastened by august Societies, such as the Indian Society of Weed Science, or the Asian-Pacific Weed Science Society making a conceptual shift and taking a stand decisively to encourage their constituency to consider accepting the reality of 'living with weeds'.

Many of the developed and affluent nations have been built on technology, which resulted from the industrial revolution of the past two centuries. Accumulation of material wealth is deeply entrenched in such societies. They place little emphasis on the collective 'traditional wisdom' upon which sustainable societies are usually based. A good example is Australia, which was colonized by Europeans only 230 years ago. From the first fleet, which arrived in 1788, the new colonisers introduced many European herbs and wild plants into Australia, and many are now considered invasive species. The European colonisers and subsequent waves of white immigrants then developed an attitude of resisting others from entering the country, a kind of xenophobia. Many pioneer farmers, with deeply ingrained perceptions, often mistrust alternatives. As a result, except for a few 'enlightened' people, farmers generally malign weeds, because weeds are erroneously perceived as the most significant factor, which reduces the profitability of human endeavours. The lack of discussion on beneficial effects of weeds in agricultural landscapes and utilization possibilities contributes to the prevailing view that most weeds are of no value. There is also a perception in developed countries, where every human action needs to be justified based on cost, that utilization of weeds, such as harvested aquatic weeds, is costly and, therefore, not economically worthwhile. Nevertheless, the question needs to be asked: *Should human endeavour always be measured in monetary terms?* Investing in utilization of weeds is justified not just because it is common sense and a good management practice, but also because provides a positive, cultural message of sustainable living for human societies.

Creating a 'weed-literate' society: Making the case for utilization of weeds is not difficult, but creating a more 'weed-literate' society, overcoming the bias against weeds, is more difficult. The compilation of existing knowledge from different cultures should assist this task, and, in this sense, there is much to learn from economic botany and ethnobotany 'bodies of knowledge'. One way of promoting weed-literacy even among weed scientists is to invest in investigating the ecological role of weeds in agro-ecosystems and the environment in any project, bearing in mind that they have both negative and positive impacts.

A set of mandatory question in any new weed science grant application should be:

"*Have you considered the values of the weeds you are targeting for control? Explain*"

"*Have you considered the likely environmental impact (benefit or otherwise) of your proposed weed management actions? Explain*"

"*What are the risks and benefits of your proposed weed management actions? explain*"

The answers should reflect thoughtful, ecological considerations bythe proponents on theintrinsic values of the species and populations they are attempting to manage, as well as on the unintended impacts or non-target effects (*e.g.* herbicide or pesticide spray drifts, or soil disturbances) on multiple interactions of species through food webs, *etc*. The proponents should also clarify why some levels of pioneering species could not be tolerated. August weed societies should also lead by creating the theme 'utilization of weeds as bio-resources' or 'beneficial impacts and uses of weeds' as part of their future mandate, encouragingtheir members, associated innovators, entrepreneurs and farmers to explore more broadly theopportunities presented by weeds.

Weeds will always present a stimulating challenge

Without doubt, weeds have contributed enormously to the development of human innovations. From the earliest developments of agriculture to the modern agricultural revolutions, they have challenged our way of living. This has led to inventions from the earliest digging sticks to sophisticated machinery, and to the development of agronomy, irrigation, surveying, and eventually the agrochemical industry. The development of genetically modified crops by multi-national biotechnology companies during the last two decades also falls into this category. Weed scientists have been involved in the development of glyphosate-resistant cotton and soybean by Monsanto, glufosinate-resistant cotton and soybean by Bayer; these are already in the market. There are other products, which are in the pipeline (*i.e.* dicamba-resistant crops by Monsanto; 2,4-D resistant corn and soybean by Dow). The advances in biotechnology that have created modified organisms that can be grown and harvested on a large scale to feed growing populations must rate high in the continuum of human innovation. The stimulus that profits can be made from such innovations came from the challenge offered by weeds.

Colonising species will always be the ultimate survivors in the conflict with man. Rather than a zero tolerance towards particular taxa, it would seem reasonable to propose 'ecological management' of problematic populations, with an eye on their potential benefits, on a 'case-by-case' basis. This requires synecological models that capture all of the key factors that govern the dynamics of populations in a given location. synecology is the branch of ecology that deals with the structure and development of entire ecological communities, their interactions with the chemical and physical environment, and the complex interrelationships between all plants and animals within them. These differ from autecological, 'species-led' approaches that are more concerned with the reactions of single species. The agroecology approaches (Altieri 1988, 1995, 1999) are invaluable ecological risk management models in the sense that the practices promoted have long-proven benefits in ecosystems. They also encourage positive thinking, linking people with nature, and stimulate people to closely integrate with all components of biological diversity, including 'colonising species.

An ethno-biological perspective -link between plants and humans: As discussed in this essay, humans have for long used colonising species as foods, medicinal plants, animal feeds, housing materials, and raw materials for handicrafts, ornaments, etc. Before these beneficial uses are forgotten, priority should be given to investing and recording of the ways in which traditional cultures have used weeds. To achieve this objective, more cooperative research funding is needed to consolidate our knowledge of their ecological roles, and on utilization of weeds as resources.

Discussing the relative variety and intensity of uses of common reed, *Phragmites australis* by human groups, Kiviat and Hamilton (2001) concluded that the utility value of a plant to humans is related to: (1) abundance and distribution of the plant; (2) length of time the plant and a human group have been in contact; (3) invention or transmission of traditional ecological knowledge of the plant; (4) ease of managing, acquiring, and processing the plant; (5) its physical and chemical qualities (*e.g.* pharmaceutical or toxicological properties, fiber characteristics, nutritional values); and (6) availability and quality of alternate species. Discussion of such ethno-biological perspectives is essential to building better relationships of plants by humans, particularly where the conflicts between the two are more profound.

The importance of traditional cultures, their wisdom and sustainable interactions with plants and animals are routine subject matter in anthropology, and social science. Interactions between the humanities and a discipline like weed science are not strong; and hence, both sides may gain from a closer exchange of views. Journals dedicated to ethnobotany, and economic botany, often carry articles relating to human uses of colonising plants. Increased appreciation of plant resources can be achieved by studying these ethno-biological appraisals. Improved understanding of plants of value to humanity will also assist 'weed risk assessments' when people are asked to decide whether or not to list particularly resourceful taxa as 'invasive'. *Applying 'a guilty until proven innocent' approach to taxa with colonising abilities, as currently practiced, belies common sense, is disrespectful to nature, and will not be tenable in the long-term*.

In contrast to the negative attitude towards weeds prevalent in highly industrialised countries, traditional societies all over the world have used plants and weeds wisely and have 'co-existed' with them. Are there not lessons from previous generations and indigenous cultures that plant resources should be respected rather than maligned? In the attempt to maximise agricultural production, anything other than the crop plant whose yield brings profit is regarded as undesirable. This flawed view is not sustainable under the commonly accepted principles of ecologically sustainable development, to which, paradoxically,even affluent nations have beencommitted.

Perhaps the 'paradigm shift' required in the field of weed science in the 21st Century is to recognise the potential of colonising plants as 'bio-resources' and to find ways to integrate them into our lifestyle rather than over dramatising the negative aspects of plants regarded as weeds, the weed science community needs to bring about a balance and to emphasize the utilitarian value of colonising plants, with their tenacity and vitality, and to reconsider the advantages of putting these into practical use. Utilization, instead of attempts to eradicate, will lead to more effective management of weeds in most situations, where undesirable effects of a large population are untenable.

By 2025 AD the global population is expected to reach 8.5 billion, of which 83% will be living in developing countries. As a consequence, two of the greatest challenges facing mankind are to increase food production in landscapes where productivity has declined, and to achieve this while not degrading the environment. The real challenge is to increase food and fiber production in a sustainable manner, while maintaining the biodiversity, component ecosystems and landscapes for future generations. Therefore, particularly in the less affluent countries, a negative attitude towards any group of plants, including those that sometimes interfere with human affairs is unwarranted, and making such a mistake is not affordable. The examples discussed show why this is so.

In order to alleviate socio-economic hardships, and to conserve biological and cultural diversities, it is necessary to build stronger links between people and biological resources. The level of success of this depends on accommodating local knowledge, aspirations and priorities of communities, including indigenous people and farmers, with some trade-offs between development and conservation. The ultimate goal must be for the present generation to be 'custodians of landscapes', instead of being exploiters, and this task requires a proper appreciation of plant resources, including weeds.

Conclusions

As Harlan (1992) observed: "*...Weeds have been constant and intimate companions of man throughout his history and could tell us a lot more about man, where he has been and what he has done, if only we knew more about them...*". The colonising species, disparaged as 'damned weeds' were here on earth before us; and they will be here after us. They are simply an essential part of the earth's rich biological diversity, just as much as we humans are, wherever or whenever a natural disturbance occurs, or when humans disturb a habitat, colonising plants will be among the first to make use of the opportunity of available space and resources. They will always shadow humans.

In the contest with other plants, those with colonising attributes will always win. This ecological emphasis has been downplayed in a large number of publications, because the focus during the past 100 years or so has been so much on weed control, due to their negative impacts on agricultural production. *Weeds are not the culprits*; *they are just a symptom of the real cause*, which is ecologically destructive land-use practices by humans, including land clearing, monoculture cropping, overgrazing, and introductions of species for short-term profit. If weeds are to be better managed, land management practices must improve, and more broadly, all natural resources must be better managed. In natural systems, or man-made ecosystems, colonising plants serve valuable ecological functions, and these need wider and deeper recognition. Weed Scientists should focus their attention on exemplifying the complex biological interrelationshipscolonising plants have with other biota and the environment, such as providing resources for wildlife, slowing erosion, building soil, and generally enriching biological diversity through genetic exchanges. The future of humankind will surely depend on how well we manage our relationships with nature, and particularly, plants - our primary producers of food. It is a responsibility to manage weeds effectively, and efficiently, whilst appreciating their intrinsic worth and potential as bio-resources.

Many species of plants are currently considered as invasives that may not have much use for humanity; this attitude must change. Much of the time, publicity in developed countries, driven by media interests, gives exaggerated accounts of negative attributes of weeds. This has led to a blitz against weeds, over-emphasizing the conflict man has with some species. The fact that so many colonising species grow and coexist in the same environments with native species, as well as crops, tends to be overlooked. Because of their adaptability, weeds will always compete with other plants, like crop plants, or slow-growing perennials. Whilst the economic consequences of this interference with crops are reduced yields and quality of crop produce, whether colonising species will always cause negative ecological consequences is uncertain. Some generalities, such as weeds reduce biodiversity and the regeneration of native species, are unproven across different landscapes. For instance, a study in Canada found that introduced species were no more likely to dominate wetland ecosystems than native species; and the proportion of dominant exotic species that had a significant negative impact on wetland biodiversity was the same as the proportion of native species with a significant negative effect (Houlahan and Findlay 2004).

The widely held belief that weedy, colonising species will always threaten ecosystems overlook the fact that weeds also are part of the same biological diversityin any geographical region, area, or cropping field, enriching and stimulating biotic interactions all the time. Given that most weed invasions can never be reversed, they can only be managed by reducing their populations to a level that might be acceptable. The challenge is to deliberately and effectively managethe negative impacts of weeds in agroecosystemsor non-agricultural landscapes with the tools humans have invented, whilst reaping the ecological benefits of having some levels of weed populations.

In a strategic approach to managing weeds, the utility of these plant resources needs to be highlighted, within the field of weed science, and to do this a conceptual shift towards 'living with weeds' appears necessary. People should be encouraged to explore different ways of using weeds. The summary condemnation of plant taxa,just because someone may not like to have them in particular situations is not a sensible way to approach complex biological interactions, exacerbated by human disturbances and greed. A much broader appreciation of the useful attributes of plants and their applications in improving the human condition should be a high priority for the future generations of weed scientists. As demonstrated in this essay, the features that confer superior colonising ability and competitiveness to these plants can be very useful, not just in repairing damaged ecosystems, but also in providing future food, fibre, medicinesand other necessitiesfor all animals, including humans.

As human enterprises expand, populations increase and the pursuit of material wealth continues, the mode of existence of some colonising plant taxa will increasingly clash with our existence. It is through no intrinsic fault of these plants. The same attributes that make a plant 'invasive' will be sought after under a different set of circumstances. Acknowledging both sides of the argument, the way forward is to broaden our understanding of their crucial role as integral parts of biological communities, learn from their resilience, tenacity, and capacity to adapt to environmental disturbances. Perhaps this would help modify our attitudes, allowing us to avoid creating conflicts with plant taxa, and getting into battles that we cannot win.

As in many other fields, it is necessary from time to time, to realign the focus of a scientific discipline, and weed science may have reached that stage again. As pointed out by Harada (2001), whilst there is a vast amount of weed science literature dealing with weed management, what the future requires is a 'body of knowledge' of beneficial effects of weeds and their utilization potential to be established, so that present and future generations could benefit from that knowledge. My plea is for weed scientists to achieve this in the next decade or so. To end this essay, I would pose the following essential questionto all weed scientists and weed managers; '*Would you live in a world free of weeds*? or, would you cherish the knowledge that a vast multitude of plants, including weeds, and animals inhabit our planet, and our complex interactions with them enrich our lives? *In an environmental ethic that is all too familiar to the sub-continent - that all life is sacred - weeds are no more villainous than man himself*!

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