Development of Climate Change Effects-Reducing Information Systems towards Sustaining Medicinal and Aromatic Plants

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***Abstract**:* Economic growth has been inextricably linked with accelerating negative environmental impact. Projections show that the full climate change mitigation potential of biotechnology processes and biobased products ranges from between 1 billion and 2.5 billion tons CO_2 equivalent yearly by 2030. MAPs' species are being destroyed at an unprecedented rate and are threatened with extinction by habitat loss, climate change, overexploitation, land conversion, and deforestation. Global projections of MAPs diversity loss show that the largest losses of habitat and diversity will occur in tropical ecosystems (forest, woodland, savannah), accounting for a projected loss of 25,000 to 40,000 MAPs species by 2050. This paper presents the development of a framework for MAPs productivity and sustainability management. It establishes systems to closely monitor the change in MAPs resources and the recovery of habitats from the unprecedented effects of climate change. A logistic growth model was developed. A conservation program based on MAPs' intrinsic rate of increase and carrying capacity parameters was written in C++ programming language. The emerged system ran with varied data to ascertain population growth/harvesting and life span based on flexibility; scalability and modularity; and accuracy would reduce climate effects on MAPs; a framework that presents all the stakeholders and their respective responsibilities in the management of MAPs. The rapid loss of MAPs life has far-reaching consequences, and their loss will adversely affect future drug discovery. The increasing interest of people in MAPs commands a special attention to organize the actors and preserve the MAPs genetic resources against climate change. It is pertinent to improve access to technologies for use in a wider range of MAPs, fostering public dialogue and increasing support for the adoption and use of internationally accepted standards for life cycle analysis together with a range of other incentives designed to reward environmentally sustainable technologies.

***Key words*:** Biotechnology, Climate change, Informatics, Conservation, Medicinal and Aromatic Plants, Sustainability

Introduction

Medicinal and Aromatic Plants (MAPs) are increasing sought worldwide for various purposes and continue to attract growing interest from farmers, traders, economists, teachers, professionals, health officials and various industries. The MAPs are natural biological resources that have a great potential to synthesize a huge variety of important secondary metabolites, also referred to as natural products, far more than animal and even microorganisms. These natural compounds are used as pharmaceuticals, agrochemicals, and cosmeceuticals. Recently, MAPs also are used as functional herbal food ingredients, nutraceuticals and health products. The supply of the source plants however, is often limited due to diseases, changes in climate, and changes in the development in the growing regions [1]**.** Climate change refers to long-term changes in the earth's average temperature, precipitation and other factors. Climate disruption refers to significant climate change over a short term and long-term harmful effects. Likely effects of climate change include (1) some areas getting colder and others hotter; some drier and some wetter, (2) forest dieback and ecosystem change, and (3) more frequent and devastating forest fires which will add more CO_2 to the atmosphere **[2}.** Climate change is a 'threat multiplier' – it increases a range of livelihood threats and vulnerabilities, rather than being an isolated specific risk. The impact of changing climate on long-term trends needs to be better understood **[3].** The sustainable use of natural resources has become an unavoidable necessity from both environment protection and socio economic points of view. Currently, between 4,000 and 10,000 MAPs are on the list of threatened and/or endangered species and this number is expected to rise. These problems could be overcome through MAPs selection and cultivation under agricultural conditions which also could respond to increasing demands in terms of plant security and traceability, socio-economic development, biodiversity conservation and sustainable use of genetic phyto resources as basic inputs for the future [1]**.**

Degradation of the Natural Environment

Degradation of the natural environment and need for conservation measures are urgent concerns with ever more evidence of human activities despoiling the planet, exacerbated by current climate change predictions **[4].** Environmental degradation, mismanagement of natural resources, and unhealthy consumption patterns and lifestyles impact health. Ensuring environmental sustainability would demand encouragement of community level good practices on sustainable use as well as management of medicinal, nutritional and cultural resources **[5].** Extinction is a natural phenomenon that is part of the evolutionary cycle of species. Some estimates indicate that endangered species encompass 11% of plants, 4.6% of vertebrates, 24% of mammals and 11% of birds worldwide. Anthropic activities and man's development is a major cause of resource depletion and weakened habitat. Some 15,000 of 50,000 medicinal species are under threat of extinction. Shortages have been reported in China, India, Kenya, Nepal, Tanzania and Uganda. Commercial over-harvesting does the most harm, though pollution; competition from invasive species and habitat destruction all contribute. Commercial collectors generally harvest medicinal plants with little care for sustainability. This can be partly through ignorance, but [happens] mainly because such collection is unorganised and competitive **[6].**

Renewable Resources and Conservation

Renewable resources are under extreme pressure worldwide despite efforts to design better regulation in terms of economic and/or control instruments and measures of stocks and harvests. One focus of biodiversity economics and management is to establish an economic basis for preservation by pointing out the advantages it procures. Consequently, there is growing interest in assessing the value and benefit of biological diversity **[7].**

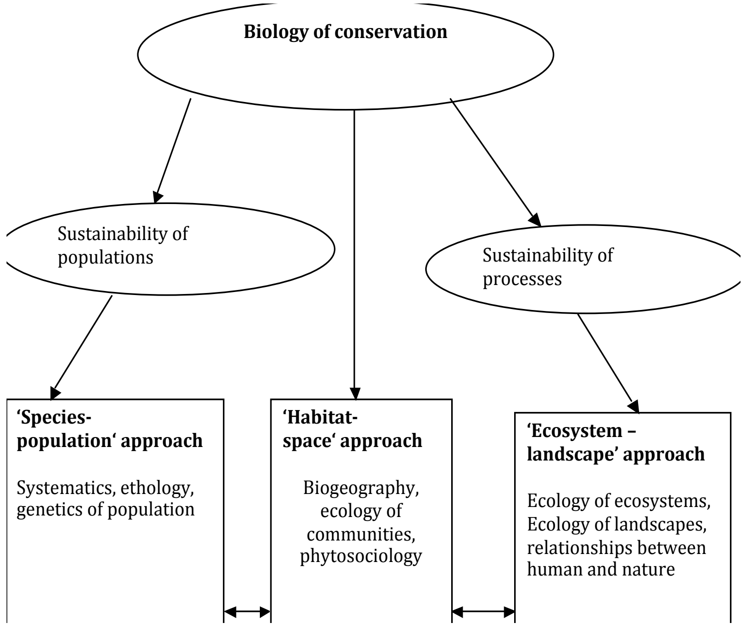

Fig. 1. Biology of Conservation [9]

To combat diminishing biodiversity and dwindling traditional knowledge, access to and exchange of information is crucial amongst researchers, scientists, policy makers and indigenous populations. To facilitate the exchange of information between these diverse users, significant information management systems are required. Information technology (IT) has dramatically changed the way scientific research is conducted, giving rise to multidisciplinary fields such as biodiversity informatics. Biodiversity informatics is a new discipline that integrates species level information from diverse domains using the scientific name of the organism as the linking thread **[8].** Biodiversity losses occur due to habitat destruction, over-harvesting, pollution, inappropriate and often accidental introduction of exotic plants and animals, etc. Biodiversity conservation is a paramount concern worldwide to preserve the natural habitats of vulnerable MAPs species and achieve sustainable exploitation in less vulnerable areas. Action should be taken now to conserve the MAPs base of traditional medicine, as well as safeguarding its potential for modem medicines in other parts of the world **[5]**. Human induced development activities are introduced with insufficient attention to their consequences for our living environment, even in cases where environmental assessments have been carried out **(Fig. 1)**. This apparent lack of attention to biodiversity in environmental assessment is rooted in the difficulties we have in adequately addressing biodiversity within the scope, time frame and budget allocated for assessments **[9].**

Materials and Methods

Logistic growth model among natural resources sustainable management models reviewed was selected for this work.

(i) ***Logistic growth model:*** To ensure populations recruit enough members to both make up for human-caused mortality and maintain a certain "safe" population level, a simple model that describes this density-dependent growth is a θ-logistic model:

$$\boldsymbol{N_{t+1} = N_t + rN_t[1 - (N_t/K)^{\theta}]} \quad (2.1)$$

where N = population size, t = time, r = maximum growth rate (near N = 0), K = carrying capacity (for illustrative purposes set at 10,000), and θ = shaping parameter that controls the level of maximum net growth. With density-dependent growth, the fastest growth rate is near N = 0, and at K the births are equal to the deaths [10]**.**

Density dependence is a central process for exploited species. The logistic model forms the basis of much theory of sustainable use. In principle, the strength and form of density dependence have a crucial influence on the impacts of harvest, and defining the process can therefore be very helpful **(Fig. 2)** in understanding and predicting outcomes **[11].**

Fig. 2 (a) The per capita growth rate (number of new individuals added to the population for each existing individual) as a function of population size; (b) The total number of new individuals added to the population as a function of population size; and (c) Yield as a function of harvesting effort, with the maximum sustainable yield shown.

(ii) ***Bioeconomic System:*** This is a modified conceptual model of the dynamics of harvesting for a village of a fixed size exploiting a closed population of a single species. The decisions and impacts of village harvesters are shown in **Fig. 3.** The harvested population has logistic growth [11]**.**

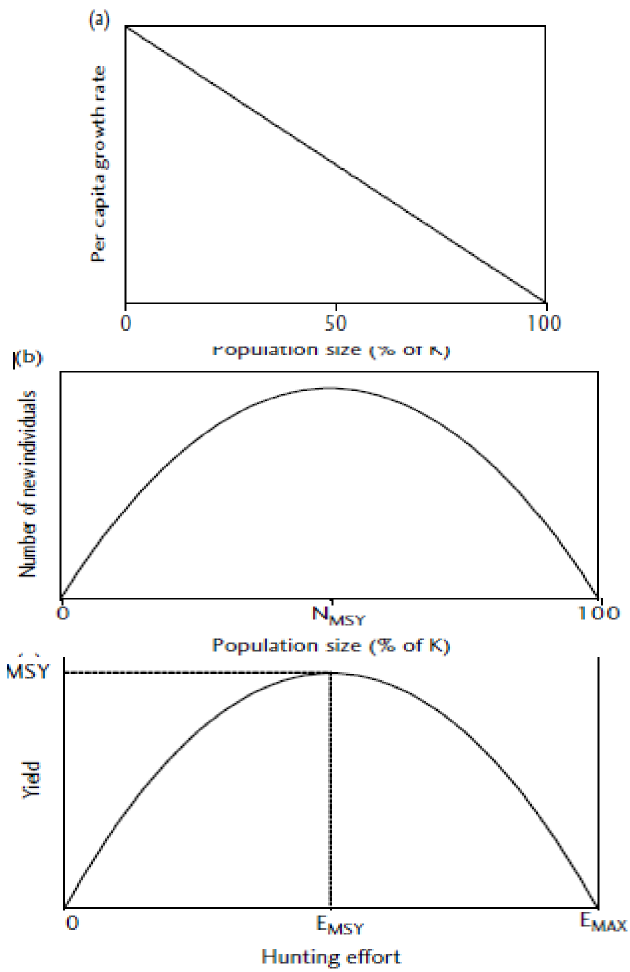

Fig.2 .The logistic growth model [11]

(iii) ***The Logistic Model*****:** The logistic growth model is the simplest model of density dependent population growth.

$$g(B) = B + rB\,(1 - B/K) \qquad (2.2)$$

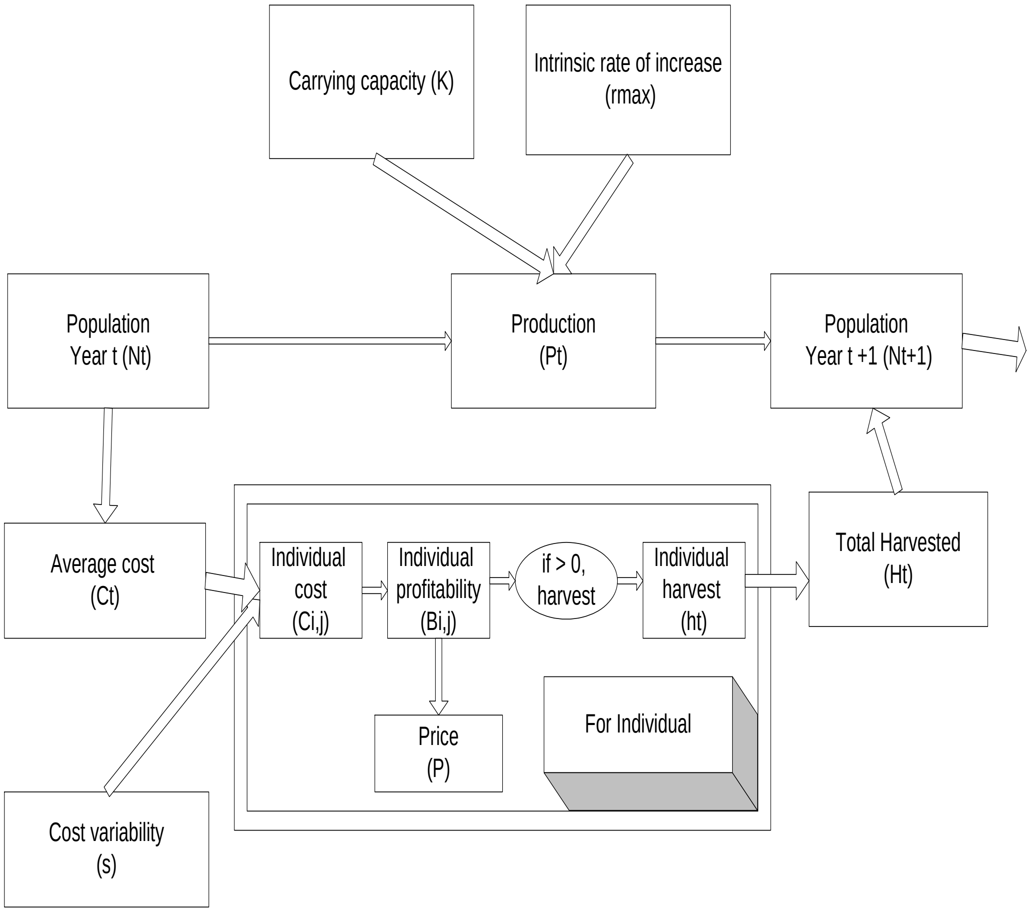

Fig. 3. Summary of a simple bioeconomic system [11].

where B stands for the resource biomass and $g : R+ \rightarrow R+$ is taken to satisfy $g(0) = 0$,
$(r = R - 1)$ $r \geq 0$ is the *per capita rate of growth* (for small populations), and K is the *carrying capacity* of the habitat. We shall also use the equivalent form

$$g(B) = (1 + r)B\,(1 - rB/((1 + r)K) \qquad (2.3)$$

Such a logistic model in discrete time can be easily criticized since for biomass B greater than the capacity K the biomass becomes negative, which of course does not make sense.

(iv) ***Harvesting*****:** When harvesting activities are included, the model above becomes the *Schaefer model*,

$$B(t + 1) = g(B(t) - h(t))\ ,\ 0 \leq h(t) \leq B(t)\ , \qquad (2.4)$$

where $h(t)$ is the harvesting at time t. Notice that, in the above sequential model, harvesting takes place at the beginning of the year t, hence the constraints $0 \leq h(t) \leq B(t)$ are right above, and regeneration takes place at the end of the year t **[11].**

Results

Fig. 4 presents all the stakeholders and their respective responsibilities in the management of MAPs. The key harvesting activity is affected by changes in business, environment, climate, MAPs population dynamics, and government policy / political scenarios as reflected in **Fig. 4**. This key activity requires strict regulation enforcement consistently in line with enumerated changes. The above are used in ascertaining the sustainability requirements. A conservation program based on plants' intrinsic rate of increase and carrying capacity parameters was written in C++ and run several times with varied values to ascertain the effect of these parameters on harvesting behaviour.

Conclusion

Climate change is a growing threat to species. Renewable resources are under extreme pressure worldwide despite efforts to design better regulation in terms of economic and/or control instruments and measures of stocks and harvests. The increasing interest of people in MAPs commands a special attention to organize the actors and preserve the MAPs genetic resources against climate change. It is pertinent to improve access to technologies for use in a wider range of MAPs, fostering public dialogue and increasing support for the adoption and use of internationally accepted standards for life cycle analysis together with a range of other incentives designed to reward environmentally sustainable technologies. Indiscriminate population growth, coupled with urbanization and overharvesting has led to erosion of precious genetic resources. In addition, extensive human intervention has resulted in global climate change, which is taking a heavy toll on natural biodiversity. To combat diminishing biodiversity and dwindling traditional knowledge, access to and exchange of information is crucial amongst researchers, scientists, policy makers and indigenous populations as demonstrated in the framework presented in this work. As Computer Science and Biotechnology communities join forces (bioinformatics and medical informatics disciplines in Health Informatics) to create new technologies for the advancement of medical science and improvement of medical service delivery, this might prove to be promising for enabling people to lead normal, healthy lives.

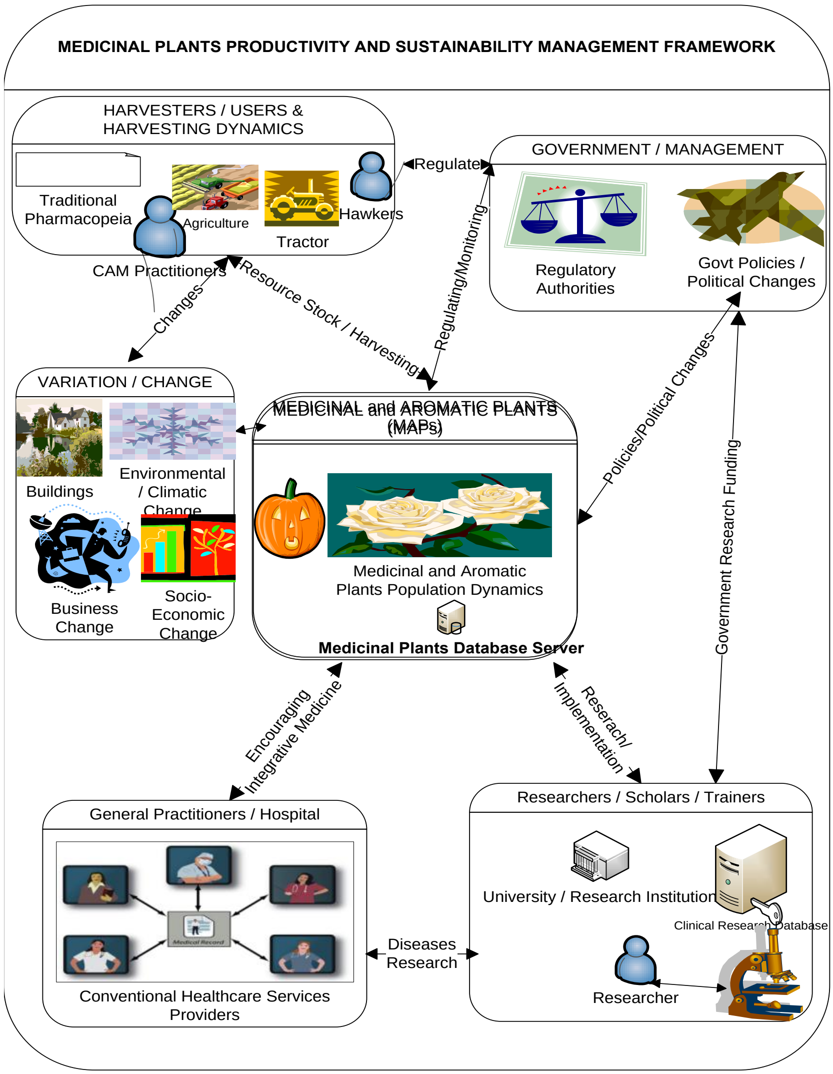

Fig. 4 Medicinal and Aromatic Plants Sustainability Framework

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