**AN AGNETS BASED APPROACH TO HUMAN AND NATURE DYNAMICS (HANDY) MODEL**

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**ABSTRACT**

**INTRODUCTION**

The phenomenon of rise and fall of civilizations has been cited to be recurrent in nature by several researchers (Chase-Dunn and Hall, 1997). HANDY (Human and Nature Dynamics) model proposed by Motesharrei et al., (2014) provides a general explanation and working model for this phenomenon. The model describes how competition for a limited, but self-regenerating resource among a population of various kinds of agents can lead to drastically different outcome for the society over time. The HANDY model has been set as an analytical problem. However, the general nature of the problem has micro- and macro- aspects; by micro- aspects we mean simple abstracted rules the agents follow in the model like extracting resource, consuming the extracted resource, and reproducing other agents. The macro aspects of the model are the outcomes, where the population/society in general reaches an optimal population, sees recurrent rise-and-collapse or total collapse of society at different rates of resource extraction and resource distribution schemes.

1. **Similarities and Dissimilarities between the HANDY Agents-Based Model (ABM) and HANDY Ordinary Differential Equations (ODE)**

Table 1 presents the values of the parameters used in the HANDY model simulation in the original published literature. We have used these values for the baseline simulation or a validation simulation of the agents-based form of HANDY model to match results of the HANDY ODE (Ordinary Differential Equation) model.

Table 1. Parameters table for the HANDY model.

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| **Parameters Symbol** | **Parameter Name** | **Typical Values** |
|  | Maximum death rate | 0.01 |
|  | Nominal death rate | 0.07 |
|  | Commoners birth rate | 0.03 |
|  | Elites birth rate | 0.03 |
| s | Subsistence salary per capita | 5E-4 |
| ρ | Threshold wealth per capita | 5E-3 |
|  | Regeneration rate of nature | 0.01 |
|  | Nature carrying capacity | 100 |
|  | Inequality factor | 1,10,100 |
|  | Depletion (production) factor | None |

**Egalitarian Societies:**

1. **Equilibrium values at optimal depletion factor**

The simulation of the egalitarian society assumes no elites and the HANDY model predicts the value for the optimal “carrying capacity”, i.e., maximum stable population of commoners in the society to be (c) as:

(1)

Where,

(2)

h is a parameter that depends on birth and death rate and the value should be between 0 and 1. The value of the carrying capacity of the nature was estimated to be ~7499 using the analytical expression. However, the way it is implemented in HANDY ABM the steady state population fluctuates around that value (Figure 1).

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1. **Equilibrium values at suboptimal depletion factor**

**References**

Chase-Dunn, Christopher; Hall, T., 1997. Rise and demise: comparing world-systems. Boulder, Colorado: WestviewPress.

Motesharrei, S., Rivas, J., Kalnay, E., 2014. Human and nature dynamics (HANDY): Modeling inequality and use of resources in the collapse or sustainability of societies. Ecological Economics 101, 90–102. https://doi.org/https://doi.org/10.1016/j.ecolecon.2014.02.014