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Multi-objective Decision Support System for Development of Efficient Farming System at Watershed Scale

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Resume

Introduction

The Millennium Ecosystem Assessment Report has revealed that a majority of ecosystem services in the world are either degraded or are being used unsustainably. The group further observed that integrated sustainable management practices, investment in and diffusion of agricultural technologies, development of water markets, empowerment of local communities in decision making, increased transparency and strategically focused national programmes are promising and effective for mitigating and reversing the trend of degradation (Anon. 2005). Participatory Integrated Watershed Management (PIWSM) is considered in India as one of the most efficient vehicle for rural transformation leading to self-sustainable development (Dhyani *et al.* 2005b). It aims to fulfill the multiple objectives of the stakeholders (farmers and government) through judicious use of all the natural and cultural resources for sustained productivity from watershed. Presently, planning and evaluation of PIWSM programme is done in a participatory mode by generating a socio-technical database. However, at the end the conclusions are based on the normative owing to multi direction values of objective functions. This is due to non-availability of techniques to integrate multi-objectives of different stakeholders, which are measured in different units and have different order of priorities (Dhyani and Samra, 2004). In this paper, an attempt has been made to integrate multi-objectives of stakeholders to develop alternative IWSM plans and evaluate their respective outcome in totality to select the best plan out of many PIWSM plans. This was done through the integration of multi-objective using mathematical programming, and creating a Multi-Objective Decision Support System. In hill and mountain agro-ecosystem, retrospective analysis of 30 integrated watershed management projects implemented by various developmental agencies revealed that these programmes have a definite positive impact on human well being and some of the ecosystem services. However, the extent of their impact varied widely among watersheds and implementing agencies (Dhyani *et al.*, 2005 a).

Material and methods

The farming community and the government are the two key stakeholders in integrated watershed management (IWSM) and decide the enterprise combination and resource use plan at the watershed level. A farmer aims to maximize his individual welfare without being concerned about the large scale negative impact of his actions on others. The government on the other hand, tries to maximize social welfare by internalizing the ill effects of individual farming activities. A retrospective analysis of IWSM revealed that there are 12 important variables, which influence the farm decision maker. These decision variables are grouped into three categories and each group consists of four variables. First group consists of those decision variables, which have one to many mapping with farm enterprises and hence cannot form an objective function. These are accessibility, land suitability, water availability and farmers preferences and are termed as model development decision variables. Second group includes those decision variables, which have one-to-one mapping with farm enterprises i.e. the impact of each enterprise on decision variable, can be measured independently. The group includes: - economic efficiency (farm income, Rs/yr), regular employment generation (mandays/year), food security (total energy value produced/year) and environmental security (total soil loss, Mg/year). This group was utilized to generate alternative land use plans by assigning different numerical weights to them under the constraint that the total sum of the weights is unity and using compromise multi-objective programming (MOP) techniques. The third group of decision variables can be measured from the final output i.e. watershed plan because they have many is to one mapping. This group includes cropping intensity (%), crop diversification index, cultivated land utilization index and forest dependency (%) and were measured for each IWSM Plan. The last two groups with eight decision variables were termed as impact decision variables. Finally, a trade-off matrix of 11 alternative IWSM plans with eight decision variables was developed for Khootgad watershed from Uttaranchal state of India. The watershed represents the sub temperate climate of inner Himalayas. Pine and oak are the prominent forest species while apple, pear, and almond are the major horticultural species. Paddy, maize and wheat are prominent food crops and peas, potato, cabbage, radish are the important vegetable crops. Buffaloes, cows and goat are the livestock reared by the inhabitants of the watershed.

Impact decision variables were normalized through appropriate score functions and were prioritized as per the farmers preferences, government requirement and their combined priority. Using an additive value function and importance order of the decision variables, all possible weights of that can be possibly be assigned to decision variable values, subject to the condition that sum of weights is unity, were generated. The best and worst composite score of each IWSM plan was obtained through a generic multi-objective decision support system software "FACILITATOR".

Results and Discussion

Alternate land use plans were prepared and scores analysed using the Facilitator. The results of the analysis are presented in Fig. 1. The total composite best (worst) score bar of the IWSM plan solely aiming to minimizing soil loss is at the bottom and on left side corner of the bar diagram. It reveals that this plan is most inferior among all other alternatives and has the least probability of being accepted by the farming community. The result obtained using farmers priority i.e. composite score bar, do not provide any clear-cut superiority of one plan over other. However, comparison of mid value along with variation in worst and best composite score i.e. the length of the bar, indicate that the developed IWSM plans CP_2L_1 and LPNR have an edge over the others.

When these 11 alternative IWSM plans were evaluated with the government priority order with the same scoring functions, the results became clearer. Under this CP_2L_2 and CP_1L_1 plans clearly show that they are better than the existing plans except CP_1L_2 and CP_3L_2 IWSM plans which are clearly better than all the others.

The ranking of all the alternatives employing combined priority order of both the stakeholders (farmers and government) with same scoring function showed clear-cut demarcation among alternatives. Plans labeled as CP_2L_2 and CP_1L_1 are superior than the others since they have least variability and higher mean score. The study concludes that use of MODSS techniques has a potential to generate plans for self-sustainable farming system and that these plans are adoptable since they are developed on the basis of priority of the stakeholders. Land use plans made using MODSS techniques for small land holders can be cost effective, since the plans are simulated using field information for all important inputs. These simulated plans can reduce the time required to achieve self-sustaining agriculture and environment goals since these goals are otherwise achieved after implementation of the project and refinement involving efforts spread over many years. Efforts are needed to investigate the objectives of the stakeholders and popularization of this technique for generating alternate watershed plans for environmentally sensitive areas.

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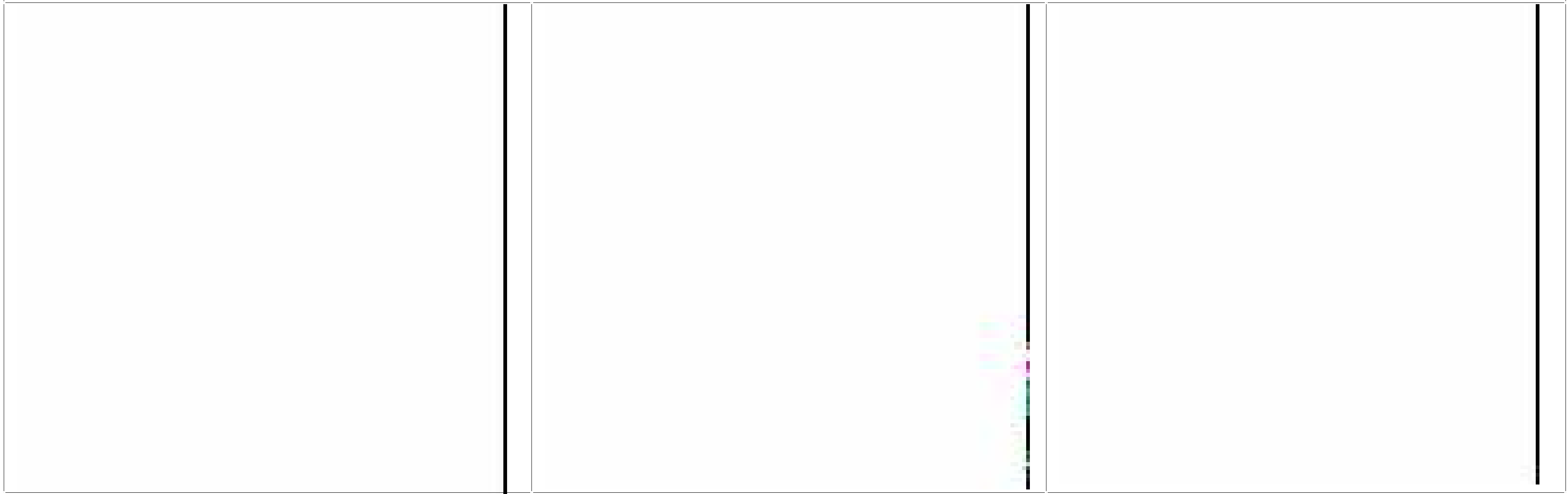
Ranking of different plans for Khootgad water l as per



Farmers' priority	Government's priority	Combined priority

Fig. 1: Graph bars containing all possible composite scores for alternative plans tested for Khootgad watershed for farmers, Government and combined priority of stakeholders