Agricultural land use optimisation using many-objective preference-inspired co-evolutionary algorithm

M-M. Memmah[1,4], L. Roques[2], M. Ciss[1,3], N. Parisey[3], S. Poggi[3], X. Yao[4]

1. INRA, UR1115 PSH, Domaine Saint Paul, F-84914 Avignon Cedex 9, France
mmouldsidi@paca.inra.fr
mamadouciss@hotmail.com
2. INRA, UR546 BioSp, Domaine Saint Paul, F-84914 Avignon Cedex 9, France
Lionel.roques@avignon.inra.fr
3. INRA, UMR1349 IGEPP, Domaine de la Motte, BP 35653, 35650 Le Rheu Cedex, France
Sylvain.poggi@rennes.inra.fr
nparisey@rennes.inra.f
4. CERCIA, School of Computer Science, University of Birmingham, United Kingdom
x.yao@cs.bham.ac.uk

Keywords: combinatorial optimisation, land use, many-objective optimisation, PICEA-g.

Abstract

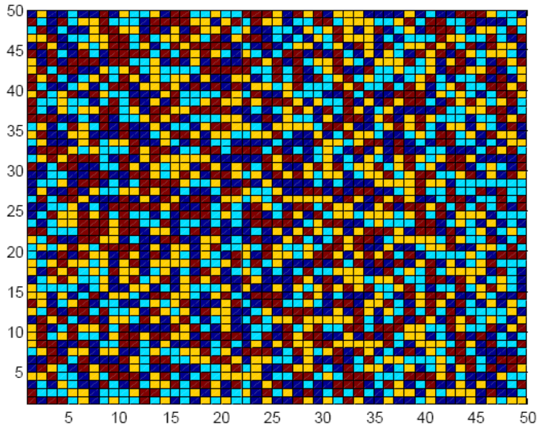
Agricultural systems are amongst the major sources of environmental pollution urging decision-makers to identify alternative management options and practices reducing the reliance on external chemical inputs, especially pesticides. The land use management practices could favour the bio-control of pest populations by predators and parasitoids and thus help to reconcile viability of agricultural systems and environment protection. The idea there is to optimize the land use management to take advantage of regulation service provided by farmland biodiversity in order to switch from intensive agricultural systems towards more sustainable ones. Agricultural land use optimisation is a complex task involving many stakeholders and decision-makers spatial factors, attributes, constraints and multiple conflicting objectives. Model-based design is useful for providing the decision-makers with a tool allowing them to explore the large number of land use combinations. Such an approach relies on models simulating the population dynamic of both pests and their enemies and optimization techniques. Therefore, even if the design of land use scenarios has been deeply studied in the literature as multi-objective optimization problems most of these works focus on either wilderness or urban settings, but we believe that agricultural landscape provides a more challenging setting.

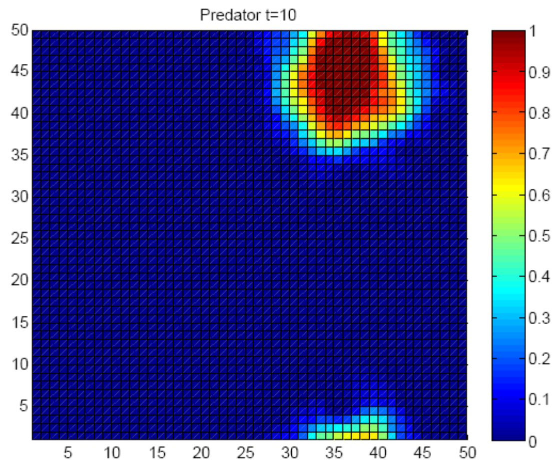
In the present study, we consider an agricultural landscape composed of n fields organised in a lattice with n_l lines and n_c columns. We consider four land use possibilities, to be optimally attributed to the fields, namely: semi-natural habitat, crops with no insecticides use, crops lowly treated (moderate use of insecticides) and conventional crops (excessive use of insecticides). The land use allocation aims to optimize 5 criteria regarding ecological (equilibrium between pests and predators); environmental (insecticides use reduction), economical (incomes of farmers), agronomical (damages induced by pests), and technical (equi-distribution of crops) issues. In this first formulation, we do not take into account any constraint.

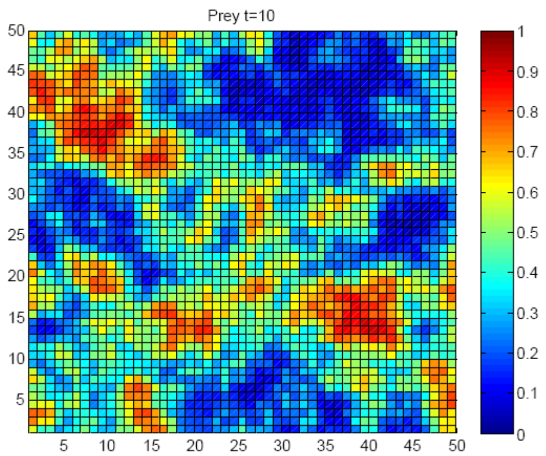
We thus deal with an unconstrained many-objective optimisation problems (i.e. more than three objectives). The Pareto dominance-based evolutionary algorithms are inappropriate in the context of such kind of optimisation problems. Indeed, it has been shown that when the number of objectives increases, the number of non-dominated solutions becomes rapidly equal to the population size, i.e. all solutions are Pareto equivalent. The scalability of evolutionary multi-objective optimisation algorithms to many-objective optimisation problems has been treated through different approaches. Ishibuchi et al (2008) distinguished the following ones: modification of the Pareto-dominance relation, introduction of different ranks, use of indicators functions, use of scalarization functions, use of preference information, and reduction of the number of functions [1]. Many algorithms implementing these modifications are available in the literature.

Here, we used the Preference-Inspired co-Evolutionary Algorithm with goals PICEA-g in which goal vectors are taken as preferences and are co-evolved with the candidate solutions during the search [2].

In each generation, PICEA-g generates new goal vectors within pre-defined bounds reflecting the decision-maker preferences (see [2] for more details on PICEA-g). We coupled this algorithm with a discrete Lotka-Volterra model simulating the population dynamics of pests (preys) and their natural enemies (predators). The obtained results show that PICEA-g was able to identify some alternative land use management scenarios allowing good trade-offs between the 5 considered criteria. The trade-offs solutions depend on economic and biologic parameters of model. The figures shown below illustrate the final populations of pests and predators for a given land use scenario.







This work is part of an ongoing project [3] and many perspectives have to be considered in the short future. We expect to take into account constraints on the spatial organisation of the whole landscape (neighbourhood between crops, ratio to be allocated to different species, compactness of crops in the landscape). We shall also consider using alternative algorithms dedicated to deal with constrained combinatorial many-objective optimisation in order to compare their performances. Also, more realistic landscapes shall be considered instead of a lattice representation.

References

[1] Ishibuchi, H., Tsukamoto, N., & Nojima, Y. Evolutionary many-objective optimization: A short review. IEEE Congress on Evolutionary Computation CEC 2008, Hong Kong, 1-6 June 2008.

[2] Rui, W., Purshouse, R. C., & Fleming, P. J. (2013). Preference-Inspired Coevolutionary Algorithms for Many-Objective Optimization. Evolutionary Computation, IEEE Transactions on, 17(4), 474-494

[3] PEERLESS project, http://www.agence-nationale-recherche.fr/en/anr-funded-project/?tx_lwmsuivibilan_pi2[CODE]=ANR-12-AGRO-0006