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SUSTAINABILITY ASSESSMENT OF KEY ARABLE CROPPING SYSTEMS IN THE KOTAYK MARZ OF RA

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In the context of a regional FAO project (GCP/RER/040/EC) (Improving capacities to eliminate and prevent recurrence of obsolete pesticides as a model for tackling unused hazardous chemicals in the former Soviet Union) covering a wide range of possible issues regarding pesticide management, a survey was performed to assess the sustainability of key arable cropping systems in the Republic of Armenia using the DEXiPM® (DEXi Pest Management) model. The continuous winter wheat (CS1), the winter wheat-maize-spring barley (cover crop) + alfalfa – alfalfa – alfalfa-alfalfa rotation (CS2) and the continuous potato system (CS3) were identified as the three key arable cropping systems in the Kotayk marz of the Republic of Armeniabased on the high importance of these crops in this country (i.e. food crops, high area cultivated, market potential).The Kotayk marz (province) was chosen as a case study for all cropping systems and more specifically the Hrazdan region for the CS1 and CS3and the Abovyan region for CS2. The DEXiPM® model showed that all cropping systems are not economically sustainable, with the CS1 receiving a 'low' evaluation, whereas CS2 and CS3 a 'very low' evaluation. CS3 had the highest production costs (high cost of pesticides and fuel), but also higher labour costs in comparison to the other systems. CS1 and CS2 were evaluated by DEXiPM as having a high environmental sustainability, whereas CS3 had a very low sustainability. Evaluation of the social sustainability of the systems indicated that CS1 and CS2 have a low sustainability. CS3 in this case received a medium sustainability score.

INTRODUCTION

The total area of agricultural land of the Republic of Armenia is 2077.0 thousand hectares, of which 449.2 thousand hectares are arable land (basic crops are winter and spring grains, potatoes and vegetables), 33.0 thousand hectares are perennial plantations (including fruits and some horticultural crops), 128.3 thousand hectares are hayfields, 1067.2 thousand hectares are pastures and 399.3 thousand hectares are other lands. Grain and legume crops occupy 55.1% of total arable land, of which 10 % is potatoes, 10.7% vegetable crops and 23.1% perennial grasses. Farm sizes in average are in the range of 0.5 to 1.4 ha.

Within a regional FAO project (GCP/RER/040/EC), a survey was conducted to assess the sustainability of key arable cropping systems in the Republic of Armenia using the DEXiPM® (DEXi Pest Management) model [1] aiming to identify the key issues and provide recommendations for their improvement.

DEXiPM® (DEXi Pest Management) was developed by the French National Institute for Agricultural Research (INRA) and within the EU project ENDURE (European Network for Durable Exploitation of Crop Protection Strategies). DEXiPM has been submitted for appreciation by European scientists from various disciplines (agronomists, weed scientists, plant pathologists, sociologists, economists) and is a hierarchical and entirely qualitative multi-criteria decision-aid model (Fig. 1), based on the DEXi software [2]. This model can evaluate all aspects of the sustainability of existing cropping systems, diagnose their strengths and weaknesses and, on this basis, encourage discussions for improvements/recommendations [1].

OBJECTIVES AND METHODS

The overall sustainability has been divided into the usual three dimensions of sustainability (Fig. 1): social, environmental and economic [3]. Special attention has been paid to the biodiversity and the social parts in DEXiPM. Social sustainability has been divided into three indicators:

supply chain, the social sustainability for the farmer and the interaction of the system with society. The biodiversity part of the tree has been developed based on some investigations [4-6]. The economic sustainability is divided into profitability or short term viability (taking into account the gross margin and subsidies) and medium and long term viability, including the financial autonomy of the farm and its capacity to invest [7]. In the whole tree, forty-three basic indicators characterize the cropping systems, including the crop sequence and the crop management of each crop and between crops (including the management of cover crops). Thirty-two basic indicators describing the context (impacting the results of the sustainability evaluation) are grouped into the pedoclimatic context, the regional context and landscape context (e.g., open fields), the economic context (including subsidies), the farm context (including material, advisory network), and social context (farmer and society perception of the system) [1]. Outputs of DEXiPM are the qualitative evaluationof each indicator of the tree including the evaluation of the overall sustainability of the cropping system.

The methodology followed to gather data for the sustainability assessment of key cropping systems in theRepublic of Armeniainvolved a three-step approach:

* First step - identification of the three-key (most common) arable cropping systems (continuous or rotated systems) in the country; cooperation with other experts (e.g. Ministry, academics, extension services);

* Second step - description of each system identified in terms of crop and pest management (i.e. pesticide and fertiliser inputs, irrigation etc.);

* Third step - provision of values for the DEXiPM inputs (economic, environmental and social indicators) according to systems' descriptions;

* Final step - feeding the model with the inputs and assessing/analysing the sustainability of each system.

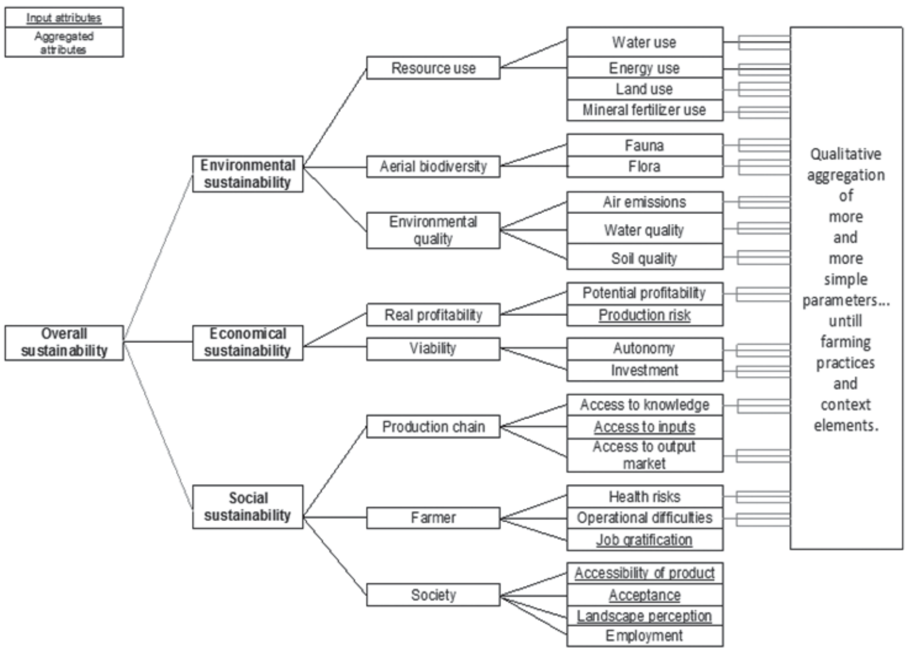

Fig. 1. *DEXiPM structure*

RESULTS AND ANALYSIS

The continuous winter wheat (CS1), the winter wheat-maize-spring barley (cover crop) + alfalfa-alfalfa-alfalfa-alfalfa rotation (CS2) and the continuous potato system (CS3) were identified as the three keyarable cropping systems in the Kotaykmarz of the Republic of Armenia based on the high importance of these crops in this country (i.e. food crops, high area cultivated, market potential). Main agronomic characteristics of the current cropping systems assessed with DEXiPM can be seen in Table.

The Kotayk marz was chosen as a case study for all cropping systems and more specifically the Hrazdan region for the CS1 and CS3 where there are ydromorphic soils with medium runoff risk and medium erosion risk, and the Abovyan region for CS2 where there are ydromorphic soils with low runoff risk and low erosion risk. This marz is characterised mainly by dry continental climate and precipitation from 400mm to 800mm per year. The DEXiPM® model showed that all cropping systems are not economically sustainable, with the CS1 receiving a 'low' evaluation, whereas CS2 and CS3 a 'very low' evaluation. All systems have a very low yield evaluation linked to risk of water stress and lack of suitable tolerant cultivars for CS1, and risk of nitrogen stress for CS2 and

CS3, clearly affecting the profitability of the systems. The slightly better evaluation of the CS1 is due to the higher gross margin of this system, linked to the lower production costs (i.e. low pesticide input and no irrigation costs) and the very low labour costs (i.e. very low number of hours). On the other hand, the CS3 had the highest production costs (high cost of pesticides and fuel) resulting in a very low evaluation of the gross margin, but also higher labour costs in comparison to the other systems due to high number of interventions. CS1 and CS3 have a low autonomy due to high specialization of the systems (gross margin depending on one crop), whereas all systems have low investment capacity (requirement for agricultural equipment and low financial security of the farms).

CS1 and CS2 were evaluated by DEXiPM as having a high environmental sustainability, whereas CS3 had a very low sustainability due to high resources use (energy and water use), a very low environmental quality (water and soil quality, and air emissions) and a very low aerial and above soil biodiversity (fauna and flora) in comparison to the other low-input systems. The only difference between CS1 and CS2 was the very high evaluation of biodiversity for CS2 because of the crop diversity in the rotation that enhances the fauna and flora diversity.

The difference between systems for various environmental indicators that are impacted by the pesticide input can be seen in Figure 2. In terms of water quality, the pesticide profile risk was evaluated as high for the CS3 because of the high pesticide applications in this system (Total Pesticide TFI including the tuber treatments) and the medium evaluation of the pesticide eco-toxicity (i.e. environmental toxicity of products applied depending on the active ingredients), whereas the pesticide leaching is the same with CS1 due to the high quantity of herbicides' active ingredients applied (>500 g a.i. ha-1) and the higher leaching risk (soil and climate) compared to CS2. Soil quality in CS3 is also affected by the high chemical disturbance (high TFI together with the medium soil coverage at pesticide application) but also the air emissions due to high pesticide volatilisation in contrast to the other systems. CS1 and CS2 resulted in high biodiversity of flora and fauna due to low TFI of herbicides and no application of insecticides respectively contrary to CS3.

Table. *Main agronomical characteristics of the current cropping systems assessed with DEXiPM*

Country/region	Republic of Armenia, Kotayk marz		
SystemID/ Cropping Sequence	**CS1**: WW/WW[a]	**CS2**: WW/M/SB(cover crop)+A/A/A/A	**CS3**: P/P
Deep tillage & seed-bed preparation	Yes	yes (WW+M+SB)	yes
Fertiliser input	N (85-102 kg ha^{-1})	(WW) - N (85 kg ha^{-1}); (M) - N (85-102 kg ha^{-1}) and dry manure (10-15 t ha^{-1}) in late season; (SB) - N (65-85 kg ha^{-1})	N (68-85 kg ha^{-1}) and dry manure (30 t ha^{-1}) in late season 1 time/3 years
Irrigation	None	(WW) - 3 times; (M) - 5 times; (SB+A) - 2 + 1 times; (A) - 5-6 times per year	4-5 times
Mechanical weeding	None	2 operations (M)	3 operations
Seed or tuber treatments	Dividend (92 g/l difenoconazole + 23 g/l metalaxyl-m) at 200 ml/100kg seeds	(WW+SB) - Dividend (92 g/l difenoconazole + 23 g/l metalaxyl-m) at 200 ml/100kg seeds	Prestige (imidacloprid 140 g/l + pencycuron 150 g/l) at 100 ml/100 kg of seeds 1 out of 2-3 years
Pre-emergence herbicides	None	none	none
Post-emergence herbicides	1 out of 2 years with 2.4-D (2,4 dimethyl-amine salt 500 g/l) at recommended dose of 2 kg ha^{-1}	(WW) - recommended dose (2 kg ha^{-1}) of 2.4-D (2,4 dimethyl-amine salt 500 g/l); (M) - recommended dose (1.2 l ha^{-1}) of Fenagon FS (2,4 butyl ester of dichlorphenoxy acetyl glycolic acid 500 g/l)	Sencor (metribuzin 700g/kg) at recommended dose of 2 kg ha^{-1}
Insecticide	None	None	Two applications with Decis (deltamethrin 2.5%) at recommended dose of 0.15 l ha^{-1} when tubers not treated

Fungicides	None	None	Two applications with recommended dose (2.5 kg ha^{-1}) of Ridomil Gold MC (mancozeb 640 g/kg + mefenoxam 40 g/kg) depending on the climatic conditions
Potential yield	3 t ha^{-1}	(WW) - 3 t ha^{-1}; (M) - 3.5-4 t ha^{-1}; (SB) - 2 t ha^{-1}; (A) - 9-11 t ha^{-1} per year	25 t ha^{-1}
TFI[b]	1.5	0.6	4.5
WHO Class[c]	II 'moderately hazardous'	II 'moderately hazardous'	II 'moderately hazardous' and U ''unlikely to present acute hazard' for pencycuron and mancozeb fungicides
IPM level	Low	low to medium	low to medium

[a]Where A, alfalfa; M, maize; P, potato; SB; spring barley; WW, winter wheat. [b]Treatment frequency index (including seed treatments), number of full rate treatment: $TFI = \frac{1}{n}\sum_{t=1}^{t=T}\frac{D_t}{DAp_t}$ *with n: number of years in the crop sequence, T: total number of pesticide treatments, D: applied rate in commercial product, DAp: approved/registered rate for the commercial product. [c] The WHO recommended classification of pesticides by hazard and guidelines to classification 2009. WHO, Geneva. 2010. [http://www.who.int/ipcs/publications/pesticides_hazard_2009.pdf]*

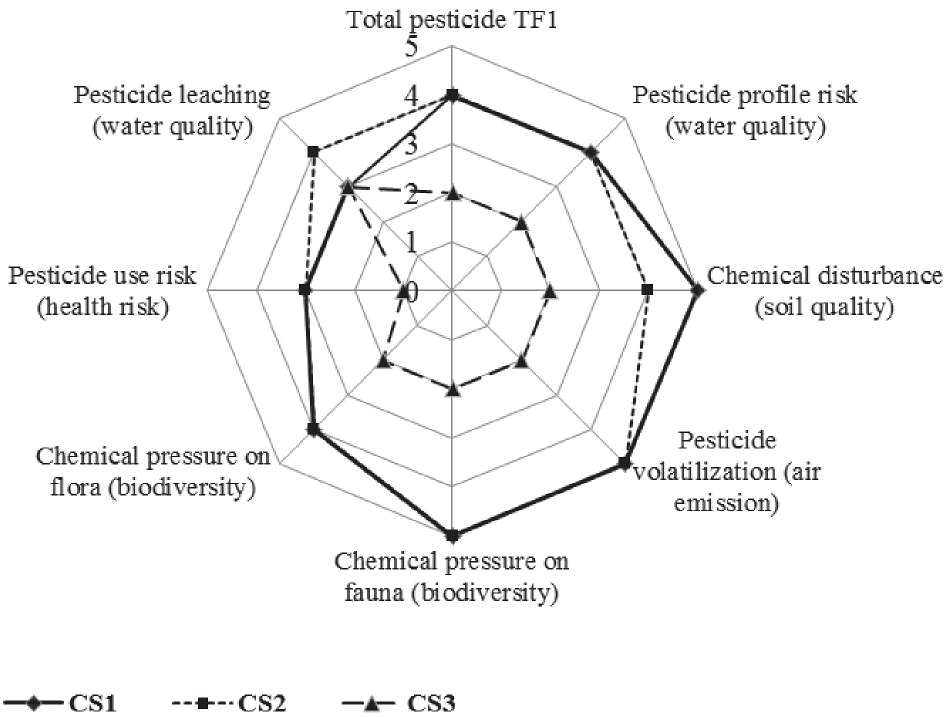

Fig. 2. *DEXiPM evaluation of various indicators as affected by pesticide input.*

[a]The five qualitative states for the Treatment Frequency Index (TFI) of pesticides (including seed treatments) corresponds to: 1: very high (>7), 2: high to medium (4.5-7), 3: medium to low (2-4.5), 4: low (0-2), 5: none.Lines indicate DEXiPM score for each system; maximum score (5) indicates the most sustainable evaluation.

Evaluation of the social sustainability of the systems indicated that CS1 and CS2 have a low sustainability due to high health risk of the farmer (high physical difficulty) and low interaction with society (low contribution to employment, especially for CS1). CS3 in this case received a medium sustainability score due to the high interaction of this system with the society in terms of contribution to employment and an affiliation to a farm support network familiar with the strategy (e.g. cooperatives). On the other hand, CS3 has a very high health risk for the farmers due to high pesticide use risk in comparison to the other systems (Fig. 2). Common weakness for all systems is the 'access to inputs' (financial and geographical (proximity) access to technologies (e.g. seeds of resistant varieties, specific equipment, pesticides, fertilisers) and common strength is the easy 'access to output market' (market flexibility and product quality in terms of risk of mycotoxin or pesticide residuals in the product).

CONCLUSION

The economic analysis identified essential weaknesses that impact the systems. Actions should be taken to improve their sustainability. It was identified that CS1 is suffering by the lack of irrigation, probably linked to not developed irrigation system in this region, but mostly by the lack of availability of potent wheat cultivars (more productive and tolerant cultivars) for the farmers because of not so developed seed industry in the country. For CS2 and CS3, a more balanced fertilization with N is recommended to cover the systems' requirements but also of P and K fertilizers as they are not used in all systems, whereas also in this case there seems to be a lack of potent crop resistant, tolerant cultivars (maize, barley and potato) for the reason mentioned before. Therefore, special attention should be given on the development of seed industry. Nevertheless, it was stressed that another major weakness in all systems that needs to be tackled is the limited 'access to inputs'. It seems that farmers don't have access to technologies (e.g. seeds of resistant varieties, specific equipment, pesticides, fertilisers), either because they are not developed or because of low awareness of farmers or due to financial difficulties. Another concern identified is that herbicide doses of 2,4-D (dimethyl-amine salt) in continuous wheat and Sencor (metribuzin) in continuous potato (WHO Class II 'moderately hazardous') are approximately the double than the ones recommended on the product labels, however this is advised as the maximum recommended dose for these products by the Bulletin of the Ministry of Agriculture of RA. A higher dose of seed treatment with Dividend (difenoconazole + metalaxyl-m) in wheat and barley was also observed (130 ml/100 kg seeds recommended on the label against Tilletias pp. Urocystistritici, Ustilagotritici and Fusarium, Helminthosporium roots). It is advised to raise the awareness among farmers, review the habit of controlling pests only with pesticides, encourage the use of crop rotation systems that will reduce the precedence of mass developments of pests and will prevent the resistance against pesticides.

Finally, the need for the development of IPM is mostly sound in the continuous potato system that has high pesticide inputs affecting all the dimensions of sustainability (economic, environmental and social). It is recommended that the introduction of monitoring systems for pests, and scouting for weeds and disease incidence together with related economic thresholds will help in the decisions of 'if', 'when' and 'what' to spray or control mechanically depending on the pest, weed and disease infestation each year, avoiding unnecessary interventions that increase production costs and the impact to the environment and farmer's health.

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ОЦЕНКА УСТОЙЧИВОСТИ ОСНОВНЫХ СИСТЕМ ЗЕМЛЕДЕЛИЯ В КОТАЙКСКОМ МАРЗЕ РА

Василеос П. Василеадис, Ян Бреитаупт, Г.В. Авакян

В контексте регионального проекта ФАО (GCP / RER / 040 / EC - Повышение потенциала для устранения и предотвращения рецидивов устаревших пестицидов в качестве модели, для решения неиспользованных опасных химических веществ на территории бывшего Советского Союза), охватывающих широкий диапазон возможных вопросов, касающихся обращения с пестицидами, был проведен опрос для оценки устойчивости основных систем пахотного земледелия в Республике Армения с помощью модели DEXiPM (DEXI борьба с вредителями). Непрерывное возделывание озимой пшеницы (СЗ1), культуроборот озимая пшеница-кукуруза - яровой ячмень (покровная культура)+ люцерна–люцерна–люцерна-люцерна (СЗ2) и непрерывное возделывание картофеля (СЗ3) были определены как три ключевые системы пахотного земледелия (СЗ) в Котайкском марзе Республики Армения на основе высокой значимости этих культур в республике (т.е. продовольственные культуры, большая площадь обрабатываемых земель, потенциал рынка). Котайкский марз (провинция) был выбран в качестве примера для всех систем выращивания культур и, в особенности Разданский регион для СЗ1 и СЗ3 и Абовянский регион для СЗ2. Модель DEXiPM® показала что все системы земледелия (СЗ) не являются экономически устойчивыми. Система земледелия СЗ1 получила „низкую“ оценку экономической устойчивости, в то время как СЗ2 и СЗ3 „очень низкую“ оценку. В CS3 были зарегистрированы самые высокие производственные затраты (высокая стоимость пестицидов и топлива), но также более высокие затраты на рабочую силу по сравнению с другими системами. СЗ1 и СЗ2 были оценены DEXiPM как имеющие высокую экологическую устойчивость, в то время как СЗ3 имела очень низкую экологическую устойчивость. Оценка социальной устойчивости трех систем земледелия показали, что СЗ1 и СЗ2 имеют низкую устойчивость. СЗ3 в этом случае получила оценку „средней социальной“ устойчивости.