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EU-CHINA Lever for IPM Demonstration

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EXECUTIVE SUMMARY

Background	EUCLID addresses needs in pest management for horticultural crops that are important in the EU and China. Innovative Integrated Pest Management solutions will be developed by the project and these will be evaluated by relevant indicators. Indicators are widely used to express the state and direction of change in the economy or environment. They can describe a state, the performance or impact of an action, the efficiency of an action, or some measure of welfare related to an outcome of an action. Indicators need to be practical and efficient to use, and should be accompanied by appropriate metrics so that the values of the indicators can be measured. A review of literature on indicators used in pest management is an early task in EUCLID as preparation for the selection of appropriate indicators with innovation developers and other stakeholders.
Objectives	Provide a list of methods and indicators that could be used to measure efficiency of pest management in farms (adopting and non-adopting IPM methods), environmental sustainability and consumer preferences. A document on selected indicators will be prepared with information on utilised sources. This will be the basis for better focusing the analysis of the economic, social and environmental impacts of IPM methodologies developed in EUCLID.
Methods	A literature review.
Results & implications	The pest management solutions, technologies and techniques being developed in EUCLID are aimed at end-user needs and benefits. They will be broadly judged in terms of how they support end-users through short-term economic advantages, environmental sustainability, social impacts and consumer preferences. At a broader social level they may also be judged in terms of how they support market introduction and maintenance of novel technologies, stimulation of scientific knowledge, and wider economic competitiveness. The many indicators identified in this review are described in a hierarchy of indicator categories. A short list of general indicators is provided, and an indicative list of potential indicators is described for the various categories of pest management solutions undergoing development in the EUCLID project.

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Introduction

This report covers the specification of a review described as part of Task 3.1 of the EUCLID project:

> ***Task 3.1.*** *A literature review covering methods and indicators used to measure efficiency of pest management in farms (adopting and non-adopting IPM methods), environmental sustainability and consumer preferences.*
>
> *Specific indicators for economic competitiveness and feasibility, environmental sustainability, consumer preferences and policy needs will be proposed by task leaders, discussed by the partners and stakeholders involved and finally selected. A scale will also be proposed for each indicator for the evaluation of the IPM strategies. Performance criteria will be elicited from developers and users for conventional and innovative control inputs.*
>
> *A document on selected indicators will be prepared with different information on utilised sources. This will be the basis for better focusing the analysis of the economic, social and environmental impacts of IPM methodologies.*

Subsequent activities also described in Task 3.1 make use of the review:

> *Secondly, to involve stakeholders, develop elicitation methods with stakeholder groups (farmers, advisers, buyers, plant health officials, etc.) for multi-dimensional evaluation of a production chain for the performance of plant protection measures.*
>
> *The task will develop descriptions of the production chains (the step-by-step practices and performance leading to crop growth, delivery and quality) for a range of farm types and areas, including all potential control options and choices. The production chains, covering pre-crop and within season control steps, will specifically identify typical conventional sets of controls and performance monitoring options through a season for a range of pests and will be compared with potential sets of compatible or alternative innovative controls.*
>
> *The analysis will consider farmers, advisers, businesses and other operational groups selected for their knowledge of the European and Chinese markets and then will be given back to researchers in WP1 and WP2 to fine tune the pest management solutions to be developed in EUCLID. This knowledge exchange will generate new insights and ideas while speeding knowledge towards practical and innovative solutions.*

The pest management solutions, technologies and techniques being developed in EUCLID are aimed at end-user needs and benefits. They will be broadly judged in terms of how they support end-users through short-term economic advantages, environmental sustainability, social impacts and consumer preferences. At a broader social level they may also be judged in terms of how they support market introduction and maintenance of novel technologies, stimulation of scientific knowledge, and wider economic competitiveness. The many indicators identified in this review are described in a hierarchy of indicator categories. A short list of general indicators is provided, and an indicative list of potential indicators is described for the various categories of pest management solutions undergoing development in the EUCLID project. Two additional frameowrks for application of indicators are illustrated, the DPSIR framework (Smeets and Weterings, 1999) and Production Chains (Quinlan et al., 2016).

Indicators are widely used to express the state and direction of change in the economy or environment (Smeets and Weterings, 1999). They can describe a state, the performance or impact of an action, the efficiency of an action, or some measure of welfare related to an outcome of an action. Indicators need to be practical and efficient to use, and should be accompanied by appropriate metrics so that the values of the indicators can be measured.

Questions basic to this review of integrated pest management (IPM) measures include: How system sustainability is assessed for IPM measures? What indicators are used? What factors influence consumer acceptance? What factors influence farmer acceptance? and, What policies promote beneficial IPM adoption?

The purpose of this review is to provide a list of potential indicators and some frameworks for considering the choice of indicators that may be applicable to pest management solutions developed in the EUCLID project. It does not at this early stage of the project identify specific indicators for each of the multitude of novel pest management measures being developed. However, from the wide list of indicators found the review demonstrates a short list of indicator dimensions and metrics that may be useful for ten classes of pest management measures that cover the range of innovations being developed in the EUCLID project.

Indicators should be applied to specific measures, and the definition of the measure is therefore important. IPM, by its nature, is a combination of individual component measures. Indicators can be applied to each component independently, or to an integrated set of component measures that would be used together as a package. Multiple component packages are likely to require more complex sets of indicators and are therefore likely to be more difficult to compare with common metrics. A catalogue of pest management innovations under development in EUCLID will need to be created as part of the process to select appropriate indicators, with the developers and other involved stakeholders.

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1. List of indicators

A review of the literature on pest management was carried out to identify indicators and metrics for management measures. Potential indicators and metrics have been drawn from 81 papers (see References) and these are listed in Tables 1 and 2. Table 1 includes single indicators in which only one dimension is measured in each instance, and Table 2 includes composite indicators that measure a variety of dimensions through a single composite or combined measure derived from several distinct measures by a formula or set of rules. Single indicators are easier to interpret, since they address only a single dimension, but they do not give the broader view that composite indices provide. Composite indices, however, inevitably put subjective weighting on different components, which may or may not reflect the user's view. Thus composite indices may be more difficult to interpret, especially if weightings are not explicit.

Many indicators proposed in the literature are not fully described with relevant metrics, but many do include metrics. Indicators are placed into general categories and subcategories, which can be sorted within the database in a spreadsheet. Some indicators may span more than one category, however. These tables are also made available on the EUCLID project website.

The review focusses on pest management and indicators used in pest management programs. However, it also covers some indicators described in wider fields of envrionmental management and food supply chain literature.

Table 1. Full list of indicators and metrics identified through a literature review.

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Consumer preferences	Consumer preferences			Labels		Gracia & de-Magistris, 2016; Van Loo et al., 2015
Consumer preferences	Consumer preferences			Price premium	$	Bonti-Ankomah and Yiridoe, 2013
Consumer preferences	Consumer preferences		Sustainability concern			Van Loo et al. (2015)
Consumer preferences	Consumer preferences			Willingness to pay (WTP)	$	Fontes et al, 2013; Bonti-Ankomah & Yiridoe, 2013; Rödiger & Hamm, 2015; Van Loo et al. (2015)
Consumer preferences	Social		Country of origin			Hwang 2016
Consumer preferences	Social		Size			Hwang 2016
Consumer preferences	Social		Production method			Hwang 2016
Consumer preferences	Social		Price		$	Hwang 2016
Cost	Environment			Effects on bee diversity	Euro/ha	Leach and Mumford, 2008
Cost	Economic			Cost of biological control agents	Euro/ha	Pure Project, 2013; FAO, 2004; OECD, 2014; Fleischer et al, 1999
Cost	Economic			Cost of fungicide	Euro/ha	Pure Project, 2013; Laborte et al. 2009; FAO, 2004; OECD, 2014; Fleischer et al, 1999; Muriithi et al., 2016; Ahuja et al, 2015

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Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Cost	Economic			Cost of insecticide	Euro/ha	Pure Project, 2013; Laborte et al. 2009; FAO, 2004; OECD, 2014; Fleischer et al, 1999; Muriithi et al., 2016; Ahuja et al, 2015
Cost	Economic			Cost of fuel	Euro/ha	Pure Project, 2013
Cost	Economic			Cost of labour for operations requiring machinery	Euro/ha	Pure Project, 2013; Pelzer et al, 2012
Cost	Economic			Cost of machinery use	Euro/ha	Pure Project, 2013
Cost	Economic			Cost of fertilizer (organic and inorganic	Euro/ha	Pure Project, 2013; FAO, 2004; OECD, 2014; Fleischer et al, 1999; Laborte et al. 2009
Cost	Economic			Cost of trap crop	$	Ahuja et al, 2015
Cost	Economic			Cost (other)	Euro/ha	Pure Project, 2013
Cost	Economic			Cost of seed	Euro/ha	Pure Project, 2013; FAO, 2004; OECD, 2014
Cost	Economic			Cost of water	Euro/ha	Pure Project, 2013
Cost	Economic			Costs of IPM practices/Costs of pesticides	$	Ortiz & Pradel, 2010
Cost	Economic			Farmyard manure cost	$	Fleischer et al, 1999
Cost	Economic			Harvesting cost	$	Fleischer et al, 1999

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Cost	Economic			Hoeing cost	$	Fleischer et al, 1999
Cost	Economic			Irrigation cost	$	Fleischer et al, 1999; Bockstaller et al., 1997
Cost	Economic			Labour costs for operations with no machinery	Euro/ha	Pure Project, 2013; Pelzer et al, 2012
Cost	Economic			Manual weeding cost	$	Fleischer et al, 1999
Cost	Economic			Polythene sheet	$/ha	Ahuja et al, 2015
Cost	Economic			Purchases of Precision Application Technology	$	OECD, 2014; US Federal IPM Coordinating Committee, 2012
Cost	Economic			Pest scouting costs	$/ha	Ahuja et al, 2015
Cost	Economic			Specific equipment needs		Craheix et al, 2016
Cost	Economic			Total cost of pest management	$/ha	Fleischer et al, 1999
Cost	Economic			Total cost of production	$/ha	Fleischer et al, 1999
Cost	Economic			Treatment of acute pesticide poisonings		Pretty et al, 2001
Cost	Economic		Total (gross) return		$/ha	Fleischer et al, 1999

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Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Cost	Economic		Total contractor cost		Euro/ha	Pure Project, 2013
Cost	Economic		Total variable costs		Euro/ha	Pure Project, 2013
Cost	Economic		Production cost		Euro/ton	Pure Project, 2013
Cost	Economic		Total input cost			Pure Project, 2013
Cost	Environment	Groundwater		Groundwater contamination	€/ha	Leach and Mumford, 2008; Craheix et al, 2016; Lindahl and Bockstaller, 2012; Leach et al, 2008
Cost	Environment	Organisms		Fish death	€/ha	Leach et al, 2008
Cost	Environment			Cost of monitoring and remediation of damaged habitats	€	Pretty et al., 2001
Cost	Environment	Organisms		Disease and insect control cost		Fleischer et al, 1999
Cost	Environment			Monitoring costs	Euro/kg	Leach et al., 2008
Cost	Health			Treatment of pesticide contaminated drinking water	€	Pretty et al, 2001
Cost	Health			Applicator effects	Euro/ha	Leach and Mumford, 2008; Leach and Mumford, 2011

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Cost	Health			Consumer effects	Euro/ha	Leach and Mumford, 2008; Leach and Mumford, 2011
Cost	Health			Human health costs		Leach et al., 2008; FAO, 2004; OECD, 2014; US Federal IPM Coordinating Committee, 2012
Cost	Health			Pesticide monitoring	€	Pretty et al, 2001
Cost	Health			Picker effects	€/ha	Leach and Mumford, 2008; Leach and Mumford, 2011
Cost	Health			Pesticide-related lost work days	Days/ year	FAO, 2004; OECD, 2014; US Federal IPM Coordinating Committee, 2012
Cost	Social			Beneficial effect	€/ha	Leach and Mumford, 2011
Economic	Social			Average net pay of farm employees		Vasileiadis et al, 2013
Economic	Social			Low cost credit		Laborte et al 2009
Energy	Environment	Energy		Energy consumption	MJ ha−1	Gracia & de-Magistris, 2016; Bockstaller et al, 1997; Halberg, 1999; Niu & Khan, 1993; Craheix et al, 2016.; Pelzer et al, 2012
Energy	Environment	Energy		Energy efficiency	(Mj Mj−1/ha/ year)	Craheix et al, 2016.; Reganold et al., 2001
Environment	Consumer preferences			Bacterial functional diversity		Floch et al., 2011
Environment	Economic			Increase in environmental stability	N/A	OECD, 2014
Environment	Economic			Ratio of soil micorbial mass to total SOM		Izac and Swift, 1994

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Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Environment	Economic			Reduced amount of pesticide residues present in waterways		Pimentel and Peshin, 2014
Environment	Environment			Reduced incidences of building resistance to pesticides		Pimentel and Peshin, 2014; Leach et al., 2008
Environment	Economic			Toxicity		Femandez-Comejo, 1998; Tsaboula et al., 2016
Environment	Environment			Deep tillage		Pelzer et al., 2012; Lindahl and Bockstaller 2012
Environment	Environment	Surface water		Aquatic effects	euro/ha	Leach and Mumford, 2008; Leach and Mumford, 2011
Environment	Environment	Organisms		Bird effects	euro/ha	Leach and Mumford, 2008; Leach and Mumford, 2011
Environment	Environment	Air		Emission of eutrophying substances (Aquatic Eutrophication Potential)	t PO4-eq.; t NOX-eq.	Niu and Khan, 1993; Vernier et al., 2013
Environment	Environment	Air		Emission of greenhouse gases(Global Warming Potential)	t CO2-eq.	Niu and Khan, 1993; Vernier et al., 2013

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Environment	Environment	Air		Emission of Non-methane volatile organic compounds, NMVOCs (proxy for ozone precursors)	t NMVOC	Niu and Khan, 1993; Vernier et al., 2013
Environment	Environment			Fertiliser Use	Kg/Ha	FAO, 2004; OECD, 2014
Environment	Environment	Groundwater		Groundwater contamination		Leach and Mumford, 2008; Craheix et al, 2016; Lindahl and Bockstaller, 2012; Leach et al, 2008
Environment	Environment	Soil		Mineral potassium consumption	t K2O-eq.	Niu and Khan, 1993; Vernier et al., 2013
Environment	Environment			N efficiency	kg N sold in products per kg N net input	Gracia and de-Magistris, 2016
Environment	Environment	Soil		P efficiency	kg P sold in products per kg P net input	Gracia and de-Magistris, 2016; Bockstaller et al, 1997
Environment	Environment	Soil		P surplus	Surplus, kg P ha−1	Gracia and de-Magistris, 2016; Halberg, 1999
Environment	Environment			Pesticide residue levels in surface water	mg/kg, ppm	OECD, 2014; Vernier et al., 2013; Waldner et al, 2001

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Environment	Environment			Pesticide residue levels ground water	mg/kg, ppm	OECD, 2014; Vernier et al., 2013; Waldner et al, 2001
Environment	Environment		Pesticides Risk Indicators		N/A	FAO, 2004; Craheix et al, 2016
Environment	Environment	Soil		Proton input/output ratio	Dimensionless	Niu and Khan, 1993; Vernier et al., 2013
Environment	Environment	Organisms		Risk to birds		Feola et al, 2011; Reus et al. 2002
Environment	Environment	Organisms		Risk to bees		Feola et al, 2011; Pure Project, 2013
Environment	Environment	Organisms		Risk to beneficial arthropods		Feola et al, 2011
Environment	Environment	Soil		Soil compaction index	Dimensionless	Niu and Khan, 1993; Vernier et al., 2013; Izac and Swift, 1994; Craheix et al, 2016; Izac and Swift, 1994
Environment	Environment	Water		Water consumption	m3	Niu and Khan, 1993; Vernier et al., 2013
Environment	Environment	Water	Risk to surface water and groundwater			Feola et al, 2011; Cruzeiro et al, 2016
Environment	Environment		Avoided Risk due to IPM			Cuyno et al., 2001
Environment	Environment		POCER			Feola et al, 2011
Environment	Environment		OHRI			Feola et al, 2011
Environment	Environment		PestScreen			Feola et al, 2011
Environment	Environment		EPRIP			Feola et al, 2011

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Environment	Environment		PIRI			Feola et al, 2011
Environment	Environment		Indicator proposed by Dosemeci et al., 2002			Feola et al, 2011
Environment	Environment		Risk to soil organisms			Reus et al. 2002
Environment	Environment			Amount of active ingredients (a.i.) of the pesticide used by weight	kg/ha	Rakesh et al., 2015
Environment	Environment			% unsprayed area		Halberg, 1999
Environment	Environment	Soil		Accommodate water entry		Reganold et al., 2001
Environment	Environment	Soil		Accumulation of contaminants		Vernier et al., 2013
Environment	Environment	Soil		Acidification/alkalinisation		Vernier et al., 2013
Environment	Environment	Air		Air emissions		Pelzer et al, 2012; Reus, 2002
Environment	Environment	Surface water		Aquatic eco-toxicity (Water quality)		Pure Project , 2013
Environment	Environment	Organisms		Bee toxicity		Leach and Mumford, 2011; Kovach et al, 1992
Environment	Environment	Organisms		Beneficial arthropod toxicity		Kovach et al, 1992
Environment	Environment	Organisms		Bioaccumulation		Reus et al. 2002; Tsaboula et al., 2016

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Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Environment	Environment	Organisms		biodiversity loss		Fleischer et al, 1999; Leach et al., 2008; Reganold et al., 2001
Environment	Environment			Bio-indicators		Liu et al, 2016
Environment	Environment	Organisms		Bird toxicity		Kovach et al, 1992
Environment	Environment	Soil		Chemical disturbances (Soil biological quality)		Pure Project, 2013
Environment	Environment	Air		Chemical pressure on fauna (Aerial biodiversity)		Pure Project - Pesticide Use-and-risk Reduction in European farming systems with Integrated Pest Management, 2013
Environment	Environment			Climatic zone		Lindahl and Bockstaller 2012
Environment	Environment	Soil		Consumption of minerals		Vernier et al., 2013
Environment	Environment			Crop diversity		Bockstaller et al., 1997
Environment	Environment	Organisms		Crop effects on pollinators		Pelzer et al., 2012
Environment	Environment	Soil		Damage to soil structure		Vernier et al., 2013
Environment	Environment	Soil		Depth of soil profile	cm	Lindahl and Bockstaller 2012
Environment	Environment			Drinking water contamination	€/ha	Leach et al, 2008
Environment	Environment	Water		Drinking water quality		Izac and Swift, 1994

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Environment	Environment	Soil		Persistence in soil DT50 (degradation half-life of pesticide)	Days	Lindahl and Bockstaller 2012; Reus et al. 2002; Kovach et al., 1992; Bottoni, 2004
Environment	Environment			Ecological structures		Bockstaller, C., Girardin, P., van der Werf, H.M.
Environment	Environment	Water		Emission of eutrophying substances (Terrestrial Eutrophication Potential)	t NMVOC	Vernier et al., 2013; Niu and Khan, 1993
Environment	Environment	Organisms		Endocrine Disruption Potential		Tsaboula et al., 2016
Environment	Environment	Organisms		Exposure Toxicity Ratios		Pure Project, 2013
Environment	Environment	Soil		Foc (Fraction of organic content) in topsoil	%	Lindahl and Bockstaller 2012; Vernier et al., 2013
Environment	Environment	Air		Fossil fuel consumption		Vernier et al., 2013
Environment	Environment		Habitat management quality			Pelzer et al, 2012
Environment	Environment	Soil	Heavy metal accumulation index		Dimensionless	Vernier et al., 2013; Niu and Khan, 1993
Environment	Environment			Heavy metal risk		Pure Project, 2013

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Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Environment	Environment			Indirect impacts on the ecosystem		Reus et al. 2002
Environment	Environment	Soil		Foc (soil organic carbon)	$cm^3\ g^{-1}$	Lindahl and Bockstaller 2012; Reus et al. 2002
Environment	Environment	Groundwater		Leaching potential/leaching risk		Kovach et al, 1992; Pure Project, 2013
Environment	Environment	Organisms		Loss of beneficial organisms		Leach et al., 2008
Environment	Environment	Organisms		Loss of domestic animals due to pesticide intoxication		Fleischer et al, 1999
Environment	Environment			Loss of food from natural resources		Leach et al, 2008
Environment	Environment	Water		Marine eutrophication		Vernier et al., 2013
Environment	Environment	Soil		Mineral fertilizer use		Pelzer et al., 2012
Environment	Environment			N Surplus	$kg\ N\ ha^{-1}$	Gracia and de-Magistris, 2016; Halberg, 1999
Environment	Environment	Air		N_2O emissions		Craheix et al, 2016
Environment	Environment			Natural enemies		Reus et al. 2002
Environment	Environment	Air		NH_3 Emissions		Craheix et al, 2016

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Environment	Environment	Soil		Nitrogen		Bockstaller et al, 1997
Environment	Environment	Soil		NO3 losses		Craheix et al, 2016
Environment	Environment			Non-productive areas		Pelzer et al, 2012
Environment	Environment	Energy		Non-renewable energy demand		Vernier et al., 2013
Environment	Environment	Soil		Organic content matter		Craheix et al, 2016; Bockstaller et al., 1997
Environment	Environment	Soil		P conservation	(kg P2O5 ha−1 year−1)	Craheix et al, 2016
Environment	Environment	Soil		P Losses		Craheix et al, 2016
Environment	Environment			Persistence in fresh water		Tsaboula et al., 2016
Environment	Environment			Persistence in water-sediment		Tsaboula et al., 2016
Environment	Environment			Pesticide treatment index (TFI)		Halberg, 1999
Environment	Environment			Pesticide use	kg/ha	Fleischer et al, 1999; Van Den Berg and Jiggins, 2007; OECD, 2014
Environment	Environment			Pesticides (synthetic, bio-pesticides) and application		Ahuja et al, 2015
Environment	Environment	Air		Pesticides emissions		Craheix et al, 2016
Environment	Environment	Soil		P-K Fertitlity		Craheix et al, 2016

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Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Environment	Environment	Organisms		Plant surface half-life		Kovach et al, 1992
Environment	Environment	Surface water		Pollution of surface water	€/ha	Leach et al, 2008
Environment	Environment			Reduction in pesticide use (a.i) by weight		Rakesh et al, 2016
Environment	Environment			Reduction in the application of highly toxic pesticides	Reduction/ha	Ortiz & Pradel, 2010
Environment	Environment			Reduction in the use of pesticides	Reduction/ha	Ortiz & Pradel, 2010
Environment	Environment			Regional intensification		Pelzer et al, 2012
Environment	Environment	Soil		Resist surface structure degradation		Reganold et al., 2001
Environment	Environment	Soil		Soil acid-base status		Craheix et al, 2016
Environment	Environment	Soil		Soil contamination	€/ha	Leach et al, 2008
Environment	Environment	Soil		Soil enzyme activities		Floch et al., 2011
Environment	Environment	Soil		Soil erosion		Craheix et al, 2016
Environment	Environment	Soil		Soil loss		Vernier et al., 2013; Izac and Swift, 1994

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Environment	Environment	Soil		Soil loss/formation ratio	Dimensionless	Niu and Khan, 1993; Vernier et al., 2013
Environment	Environment		Agro-environmental indicators (AEIs)			Vernier et al., 2013
Environment	Environment	Soil		Soil macrofauna		Craheix et al, 2016
Environment	Environment	Soil		Soil organisms (NOEC)		Reus et al. 2002
Environment	Environment	Soil		Soil pH, acidity and exchangable aluminum content		Izac and Swift, 1994
Environment	Environment	Soil		Soil structure		Bockstaller et al, 1997
Environment	Environment	Soil		SOM output/input ratio		Vernier et al., 2013; Niu and Khan, 1993
Environment	Environment			Source and availability of fuel		Izac and Swift, 1994
Environment	Environment	Soil		Stoniness	%	Lindahl and Bockstaller 2012
Environment	Environment	Soil		Subsoil texture		Lindahl and Bockstaller 2012
Environment	Environment	Air		Summer smog/ground level ozone		Vernier et al., 2013
Environment	Environment			Superficial tillage between crops (including false seedbed)		Pelzer et al, 2012; Lindahl and Bockstaller 2012

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Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Environment	Environment			Superficial tillage in the crop (mechanical weeding)		Pelzer et al, 2012; Lindahl & Bockstaller 2012
Environment	Environment	Soil		Surface loss potential		Kovach et al, 1992
Environment	Environment			Surface water		Craheix et al, 2016
Environment	Environment	Soil		Surplus and efficiencies of N, P and Cu,		Halberg, 1999
Environment	Environment	Soil		Sustain fruit quality and productivity		Reganold et al., 2001
Environment	Environment			Treatment Frequency Index (TFI) of fungicides (frequency index)		Pelzer et al, 2012
Environment	Environment			Treatment Frequency Index (TFI) of herbicides (frequency index)		Pelzer et al, 2012
Environment	Environment			Treatment Frequency Index (TFI) of		Pelzer et al, 2012

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
				insecticides (frequency index)		
Environment	Environment	Soil		Topsoil texture		Lindahl and Bockstaller 2012
Environment	Environment	Water		Toxicity to water (LC50)		Reus et al. 2002
Environment	Environment			Value of Ecosystem Services	$	US Federal IPM Coordinating Committee. 2012; OECD, 2014
Environment	Environment	Water		Water contamination		Reganold et al., 2001; Leach et al, 2008
Environment	Environment	Water		Water quality		Pelzer et al., 2012
Environment	Environment	Water		Water use		Pelzer et al., 2012
Environment	Environment	Organisms		Wild bird mortality		Leach et al., 2008
Environment	Environment	Groundwater	Risk of groundwater contamination			Reus et al. 2002
Environment	Environment	Organisms		Fish toxicity		Kovach et al, 1992
Environment	Environment	Organisms		Flora		Pelzer et al, 1992
Environment	Environment	Organisms		Flora Abundance		Craheix et al, 2016
Environment	Environment	Organisms		Flying insects		Craheix et al, 2016
Environment	Environment	Organisms	Pesticide risk for earthworms			Pure Project, 2013
Environment	Environment	Soil	Soil quality			Pelzer et al, 2012; Reganold et al., 2001
Environment	Environment	Soil	Pesticide risk for other soil organisms			Pure Project, 2013

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Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Environment	Environment	Soil	Total soil quality rating			Reganold et al., 2001
Environment	Environment	Soil	Soil quality index			Reganold et al., 2001
Environment	Environment	Water	Risk to water organisms			Reus et al. 2002
Environment	Environment		Total environmental risk			Reus et al. 2002
Environment	Environment		Difference in the potential risk, given by the Environmental Impact (EI)			Ortiz and Pradel, 2010
Environment	Environment		FEIQ -field use of the environmental impact quotient of pesticide use			Rakesh et al., 2015
Environment	Environment		Pesticide Chronic risk			Pure Project, 2013
Environment	Environment		pesticide chronic risk for aquatic organisms			Pure Project, 2013
Environment	Environment		Pesticide risk			Pure Project, 2013
Environment	Environment		Total environmental risk			Feola et al, 2011

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Environment	Environment		Environmental impact rating			Reganold et al., 2001
Environment	Environment		Environmental Yardstick EYP			Reus et al. 2002
Environment	Environment		HD			Reus et al. 2002
Environment	Environment		SYNOPS 2			Reus et al. 2002
Environment	Environment		Environmental Performance indicator of pesticides - p-EMA			Reus et al. 2002
Environment	Environment		Pesticide environmental impact indicator - Ipest			Reus et al. 2002
Environment	Environment		Environmental potential risk indicator for pesticides - EPRIP			Reus et al. 2002
Environment	Environment		System for predicting the environmental impact of pesticides - SyPEP			Reus et al. 2002
Environment	Environment		Pesticide environmental risk indicator - PERI			Reus et al. 2002
Environment	Environment		Environmental sustainability index (ESI)			Sands and Podmorea, 2000

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Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Environment	Environment		Hazard assessment			Tsaboula et al., 2016
Environment	Environment		Level of Environmental Risk			Tsaboula et al., 2016
Environment	Environment			Increase in environmental stability	N/A	FAO, 2008
Environment	Environment		Environmental Impact Quotient (EIQ)		N/A (range: 1-5)	Kovach et al. 1992; OECD, 2014; Femandez-Comejo, 1998; Leach and Mumford, 2011; Feola et al, 2011; FAO, 2008
Environment	Environment		Environmental indicator models		N/A	OECD 2005: OECD, 2014
Environment	Environment		Environmental indicator models		N/A	OECD
Environment	Environment		Pesticides Risk Indicators		N/A	OECD
Environment	Health			Bee colony losses	Euro/kg	Pretty et al., 2011; Leach et al., 2008 ; Reus et al. 2002
Environment	Health			Beneficial insect effects	€/ha	Leach and Mumford, 2008; Leach and Mumford, 2011
Environment	Health		Environmental Impact Quotient (EIQ)			OECD, 2014

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Environment	Social		Environmental Impact Quotient (EIQ)			Waldner et al, 2011
Environment	Environment	Soil		Bound residues	µg/L	Bottoni, 2004
Environment	Environment	Air		CO2 emission		Gracia and de-Magistris, 2016
Environment	Environment	Groundwater		Concentration in groundwater	µg/L	Bottoni , 2004
Environment	Environment	Air		Concentration in the atmosphere	µg/L	Bottoni, 2004
Environment	Environment	Surface water		Maximum concentration in surface water	µg/L	Bottoni, 2004
Environment	Environment	Soil		Soil micro-organism		Craheix et al, 2016
Environment				Use of low-risk pesticides	Kg	OECD, 2014; US Federal IPM Coordinating Committee, 2012
Environment	Environment		Avoided Risk due to IPM			OECD, 2014
Environment	Environment		FEIQ -field use of the environmental impact quotient of pesticide use			FAO, 2008
Farmer acceptability	Economic			Capital requirements		Laborte et al 2009
Health	Economic			Acute effects of pesticides on human health	Euro/kg and €/ha	Leach et al, 2008

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Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Health	social			Sanitary quality		Craheix et al, 2016
Health	Environment		Pesticides Risk Indicators		N/A	FAO, 2004; Craheix et al, 2016
Health	Environment		Risk of pesticides to human health			Reus et al. 2002
Health	Health			Chemical residues in food		Reganold et al., 2001; OECD, 2014; Vernier et al., 2013
Health	Health			Health costs incurred by the applicator		Fleischer et al, 1999
Health	Health			Health hazard of food stuff		Fleischer et al, 1999
Health	Health			Health risks to farmworkers		Reganold et al., 2001
Health	Health			Human diseases		Izac and Swift, 1994
Health	Health			Residues in food and water	€/ha	Leach et al, 2008
Health	Health			Systemicity		Kovach et al, 1992
Health	Health			Health risk		Liu et al, 2016
Health	Health			Customer/Com munity Health Impact	poisonin g cases, workday s lost	FAO, 2004; OECD, 2014
Health	Social			Chronic toxicity		Kovach et al, 1992

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Health	Social			Contribution to healthy and safe food		Vasileiadis et al, 2013
Health	Social			Dermal toxicity		Kovach et al, 1992
Health	Social			Mycotoxin contamination		Vasileiadis et al, 2013
Health	Social			Pesticide risk use		Vasileiadis et al, 2013; Pelzer et al., 2012
Health	Social			Risk of mycotoxin contamination		Pelzer et al, 2012
Health	Social			Risk of pesticide residues in product		Pelzer et al, 2012
Health	Social			Reduced number of health hazard caused by pesticides	Number of cases	Pimentel and Peshin, 2014
Health	Social			No. of hectares with improved practice		Veisia et al. 2016
Health	Health			Food safety		Fontes et al, 2013
Performance	Economic			Abundance of key pest and weed species		Izac and Swift, 1994
Performance	Economic			Crop performance		Reganold et al., 2001
Performance	Economic			Crop size		Reganold et al., 2001

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Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Performance	Economic			Economic losses caused by pests before and after IPM use	$	Ortiz and Pradel, 2010
Performance	Economic			Harvest Damage	%	OECD, 2014; Waldner et al., 2011
Performance	Economic			Harvest quality		Broadet al, 2009
Performance	Economic			Increased yields	t/ha	Ortiz and Pradel, 2010
Performance	Economic			Loss of crop output		Leach at al, 2008
Performance	Economic			Number of Pests/Natural Enemies	Number of Pests	FAO
Performance	Economic			Ratio of annual yield		Izac and Swift, 1994
Performance	Economic			Weed control		Craheix et al, 2016
Performance	Economic			Yield	Tons, Kg/Ha	Pure Project, 2013; Broad et al, 2009; Laborte et al. 2009; Van Den Berg and Jiggins, 2007; OECD, 2014; Fleischer et al, 1999; Bonti-Ankomah and Yiridoe, 2013; Reganold et al., 2001; Femandez-Comejo, 1998; Halberg, 1999
Performance	Economic			Yield Increase	%	Van Den Berg and Jiggins, 2007; OECD, 2014
Performance	Economic			Yield losses		Muriithi et al, 2016; Gitonga 2009; De Groote (2002)
Performance	Economic			Damage caused by pests and diseases		OECD, 2012; OECD, 2014
Performance	Economic impacts			Yield gap		Veisia et al. 2016

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Performance	Economic impacts			IPM Certification Adoption	Number growers, % growers	OECD, 2014; US Federal IPM Coordinating Committee, 2012
Performance	Environment			% weeds in grain crops		Halberg, 1999
Performance	Environment			Number of Pests/Natural Enemies	Number of Pests	OECD, 2014
Performance	Environment			Observed Biodiversity	Number of Species	FAO, 2008
Performance	Environment			Observed Biodiversity	Number of Species	OECD, 2014
Performance	Environment			Reduced incidences of pest outbreaks as a result of natural balance		Pimentel and Peshin, 2014
Policy	Consumer preferences			Labels		Gracia and de-Magistris, 2016; Van Loo et al., 2015
Policy	Economic			New supply chain emergence		Craheix et al, 2016
Policy	Economic			Presence of standards and certifications		Fontes et al, 2013
Policy	Economic			Subsidies		Pelzer et al, 2012
Policy	Economic			Subsidy inter-dependency	(% ha−1 year−1)	Craheix et al, 2016

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Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Policy	Economic			Quality of technology		Craheix et al, 2016
Policy	Social					Laborte et al 2009
Profitability	Economic			Economic efficiency	(% ha−1 year−1)	Craheix et al, 2016
Profitability	Economic			Farm profits		Femandez-Comejo, 1998;
Profitability	Economic			Farm-gate price	$/Kg	Lefebvre et al, 2011; Pure Project, 2013; Reganold et al., 2001
Profitability	Economic			Harvested crop yields per hectare	t/ha	Veisia et al. 2016
Profitability	Economic			Net farm income		Veisia et al. 2016
Profitability	Economic			Net income		Muriithi Bet al, 2016
Profitability	Economic			Producer price		Bonti-Ankomah and Yiridoe, 2013
Profitability	Economic			Product price at gate		Fleischer et al, 1999
Profitability	Economic			Profitability	Euro ha−1 year−1	Craheix et al, 2016; Laborte et al 2009
Profitability	Economic			Retail price of the product	US $	Ortiz and Pradel, 2010
Profitability	Economic			Variability in net profits		Fleischer et al, 1999

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Profitability	Economic		Net returns		$/ha	Fleischer et al, 1999; Halberg, 1999
Profitability	Economic		Increased net benefit per ha		US$/ha	Ortiz & Pradel, 2010
Profitability	Economic		Marginal utility		US $	Ortiz & Pradel, 2010
Profitability	Economic impacts		Profit Margin	Profit Margin	$/Ha	FAO, 2004; OECD, 2014
Profitability	Economic		Gross Output		euro/ha	Pure Project, 2013
Profitability	Economic		Gross margin		euro/ha	Pure Project, 2013; Pelzer et al, 2012; Laborte et al. 2009
Profitability	Economic		Profit of farm production			Izac and Swift, 1994
Profitability	Economic		Ratio of profit to farmer's target income			Izac and Swift, 1994
Profitability	Economic		Profitability			Bonti-Ankomah and Yiridoe, 2013
Profitability	Economic		Crop profitability			Reganold et al., 2001
Profitability	Economic impacts			Income increase through practicing IPM	$	Pimentel and Peshin(eds.), 2014
Profitability	Economic impacts			Amount of money saved on pest control	$	Pimentel and Peshin, 2014
Profitability	Economic/social			Farmer's improved income	$/farmer	FAO, 2004; OECD, 2014
Profitability	Social			Employment contribution	h ha−1 year−1	Craheix et al, 2016
Profitability	Social			Employment Creation/Destruction	Number of jobs, % unemplo	FAO, 2004; OECD, 2014

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Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
					yment rate	
Profitability	Social			Value of crop production per household		Veisia et al. 2016
Social	Social			Acceptability of the strategy by society		Pelzer et al, 2012
Social	Social			Access to inputs		Pelzer et al, 2012
Social	Social			Adapted machinery		Vasileiadis et al, 2013
Social	Social			Affiliation to a farm support network		Pelzer et al., 2012; Vasileiadis et al., 2013
Social	Social			Agro-chemicals		Vasileiadis et al, 2013
Social	Social			Autonomy decision making		Vasileiadis et al, 2013
Social	Social			Availability of relevant advice		Vasileiadis et al, 2013; Pelzer et al., 2012
Social	Social			Changes in farmers' attitude/ practices	% rational decisions as decisions backed by observati	OECD, 2014; FAO, 2004

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
					on and data	
Social	Social			Compatibility with certification requirements		Pelzer et al, 2012
Social	Social			Compatibility with quality requirements other than health		Pelzer et al, 2012
Social	Social			Compatibility with quantitative requirements		Vasileiadis et al, 2013
Social	Social			Education level		Vasileiadis et al, 2013
Social	Social			Environmental value		Vasileiadis, 2013
Social	Social			Evenness of workload distribution		Pelzer et al, 2012
Social	Social			Farmer and employees knowledge and skills		Pelzer et al, 2012
Social	Social			High-tech solutions		Vasileiadis, 2013

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Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Social	Social			Improvement of farmers' knowledge and skills (increased human capacity)	Number of field experiments, advice giving, management scores	FAO, 2004; OECD, 2014
Social	Social			Inversion tillage		Pelzer et al, 2012
Social	Social			Job gratification		Pelzer et al., 2012
Social	Social			Knowledge on pests		Vasileiadis et al, 2013
Social	Social			Labour requirements		Laborte et al 2009
Social	Social			Market flexibility		Pelzer et al, 2012
Social	Social			Need for highly educated people		Vasileiadis et al, 2013
Social	Social			Need for seasonal workers		Vasileiadis et al, 2013
Social	Social			Physical difficulty		Craheix et al, 2016; Vasileiadis et al, 2013; Waldner et al, 2011; Pelzer et al, 2012
Social	Social			Planting material		Vasileiadis et al, 2013

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Social	Social			Possibility to sell products for human consumption		Vasileiadiset al, 2013
Social	Social			Price justification		Vasileiadiset al, 2013
Social	Social			Proportion permanently employed people		Vasileiadis et al, 2013
Social	Social			Proportional annual pay of non-permanent workers		Vasileiadis et al, 2013
Social	Social			Repetitiveness of operations		Vasileiadis et al, 2013
Social	Social			Risk of overlapping operations		Vasileiadis et al, 2013
Social	Social			Social accessibility of product for consumers		Pelzer et al, 2012
Social	Social			Supply of raw material	(% ha−1 year−1)	Craheix et al, 2016
Social	Social			System complexity	(i year−1)	Craheix et al, 2016; Pelzer et al, 2012
Social	Social			Technical monitoring		Craheix et al, 2016
Social	Social			Technical skills		Vasileiadis et al, 2013
Social	Social			Work overload		Craheix et al, 2016

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Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Social	Social			Yearly workload distribution		Vasileiadis et al, 2013
Social	Social			Communication among farmers (advice giving frequency)	Frequency of advice giving per time period	OECD, 2014; FAO, 2004
Social	Social			Impact on management skills	Frequency of experimentation, observation, and record keeping	FAO, 2004; OECD, 2014
Social	Social			Increased numbers of consumers demand for foods produced under IPM practices	#	Pimentel and Peshin, 2014
Social	Social			Public attitude towards farmers adopting IPM	N/A	OECD, 2012; OECD, 2014

Indicator category	Impact/factor assessed (environmental/ social/economic)	Environmental matrix (if applicable)	(Composite) Indicator/index	(sub-)indicator	Metrics	Source
Social	Social			Level of public awareness about IPM	N/A	Waldner et al, 2011; OECD, 2014
Time	Economic			Labour	Labour days/ha	Laborte et al. 2009
Time	Economic/social			Pesticide application frequency		Rakesh et al., 2015
Time	Social			Number of hours		Pelzer et al, 2012
	Environment			Crop type		Pelzer et al., 2012
	Environment			Dependency on water		Craheix et al., 2016
	Environment			Dry period irrigation needs	(m3 ha−1 year−1)	Craheix et al, 2016

An interactive version of this table in Excel is available on the EUCLID project website.

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Table 2. Composite indicators identified in literature review.

Category of indicator	Impact/ aspect assessed	Environment matrix	(Composed) indicator	Indicators	Source
Profitability	Economic		**Gross margin**	Gross output-Total variable cost	Pure project 2013; Pelzer et al., 2012; Muriithi et al, 2016; FAO, 2004; OECD, 2014; Craheix et al. 2016; Broad et al., 2009; Ortiz and Pradel, 2010; Laborte et al. 2009
Profitability	Economic			**(Total input cost + Total contractor cost + labour costs for operations with no machinery) - subsides**	
Profitability	Economic			Subsidies	Craheix et al, 2016; Pelzer et al, 2012; Pure project, 2013; Pelzer et al., 2012; Muriithi et al, 2016; FAO, 2004; OECD, 2014; Craheix et al. 2016; Broad et al., 2009; Ortiz and Pradel, 2010; Laborte et al. 2009
Profitability	Economic			Cost of mineral fertilizer	Pure project 2013; Pelzer et al., 2012; Muriithi et al, 2016; FAO, 2004; OECD, 2014; Craheix et al. 2016; Broad et al., 2009; Ortiz and Pradel, 2010; Laborte et al. 2009
Profitability	Economic			Cost of organic fertilizer	Pure project 2013; Pelzer et al., 2012; Muriithi et al, 2016; FAO, 2004; OECD, 2014; Craheix et al. 2016; Broad et al., 2009; Ortiz and Pradel, 2010; Laborte et al. 2009

Category of indicator	Impact/ aspect assessed	Environment matrix	(Composed) indicator	Indicators	Source
Profitability	Economic			Cost of insecticide	Pure project 2013; Pelzer et al., 2012; Muriithi et al, 2016; FAO, 2004; OECD, 2014; Craheix et al. 2016; Broad et al., 2009; Ortiz and Pradel, 2010; Laborte et al. 2009
Profitability	Economic			Cost of fungicide	Pure project 2013; Pelzer et al., 2012; Muriithi et al, 2016; FAO, 2004; OECD, 2014; Craheix et al. 2016; Broad et al., 2009; Ortiz and Pradel, 2010; Laborte et al. 2009
Profitability	Economic			Cost of biological control agents	Pure project 2013; Pelzer et al., 2012; Muriithi et al, 2016; FAO, 2004; OECD, 2014; Craheix et al. 2016; Broad et al., 2009; Ortiz and Pradel, 2010; Laborte et al. 2009
Profitability	Economic			Cost of seed	Pure project 2013; Pelzer et al., 2012; Muriithi et al, 2016; FAO, 2004; OECD, 2014; Craheix et al. 2016; Broad et al., 2009; Ortiz and Pradel, 2010; Laborte et al. 2009
Profitability	Economic			Cost of water	Pure project 2013; Pelzer et al., 2012; Muriithi et al, 2016; FAO, 2004; OECD, 2014; Craheix et al. 2016; Broad et al., 2009; Ortiz and Pradel, 2010; Laborte et al. 2009
Profitability	Economic			Energy cost	Pure project 2013; Pelzer et al., 2012; Muriithi et al, 2016; FAO, 2004; OECD, 2014; Craheix et al. 2016; Broad et al., 2009; Ortiz and Pradel, 2010; Laborte et al. 2009
Profitability	Economic			Cost of machinery use	Pure project 2013; Pelzer et al., 2012; Muriithi et al, 2016; FAO, 2004; OECD, 2014; Craheix et al. 2016; Broad et al., 2009; Ortiz and Pradel, 2010; Laborte et al. 2009

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Category of indicator	Impact/ aspect assessed	Environment matrix	(Composed) indicator	Indicators	Source
Profitability	Economic			Cost of fuel	Pure project 2013; Pelzer et al., 2012; Muriithi et al, 2016; FAO, 2004; OECD, 2014; Craheix et al. 2016; Broad et al., 2009; Ortiz and Pradel, 2010; Laborte et al. 2009
Profitability	Economic			Cost of labour for operations requiring machinery	Pure project 2013; Pelzer et al., 2012; Muriithi et al, 2016; FAO, 2004; OECD, 2014; Craheix et al. 2016; Broad et al., 2009; Ortiz and Pradel, 2010; Laborte et al. 2009
Profitability	Economic			Marketing costs	Pure project 2013; Pelzer et al., 2012; Muriithi et al, 2016; FAO, 2004; OECD, 2014; Craheix et al. 2016; Broad et al., 2009; Ortiz and Pradel, 2010; Laborte et al. 2009
Profitability	Economic			Farm-gate price	Femandez-Comejo, 1998; Reganold et al., 2001
Profitability	Economic			Yield	Izac and Swift, 1994
Profitability	Economic		**Net margin**	Gross margin - fixed costs ((rent, property rates, property insurance), administration costs (electricity) and borrowing costs (interest on loans, vehicle leasing costs))	Pure project 2013; Pelzer et al., 2012; Muriithi et al, 2016; FAO, 2004; OECD, 2014; Craheix et al. 2016; Broad et al., 2009; Ortiz and Pradel, 2010; Laborte et al. 2009 Fleischer et al, 1999; Veisia et al., 2016; Halberg, 1999
Environment	Environment	soil	Soil degradation		

Category of indicator	Impact/ aspect assessed	Environment matrix	(Composed) indicator	Indicators	Source
Environment	Environment			Soil compaction	
Environment	Environment			Soil acid-base status	
Environment	Environment			P-K Fertitlity	
Environment	Environment			Pests and disease control	
Environment	Environment		**Environmental Impact Quotient - EIQ**	EIQ={C[(DT*5)+(DT*P)]+[(C*((S+P)/2)*SY)+(L)]+[(F*R)+(D*((S+P)/2)*3)+(Z*P*3)+(B*P*5)]}/3	Kovach et al. 1992, Sharma at al. 2015, FAO 2008, OECD 2014, Leach and Mumford 2011; Rakesh et al., 2015; Waldener et al., 2011
Environment	Environment			DT = dermal toxicity	Kovach et al, 1992
Environment	Environment			C = chronic toxicity	Kovach et al, 1992
Environment	Environment			SY = systemicity	Kovach et al, 1992
Environment	Environment			F = fish toxicity	Kovach et al, 1992
Environment	Environment			L = leaching potential	Kovach et al, 1992
Environment	Environment			R = surface loss potential	Kovach et al, 1992
Environment	Environment			S = soil half-life	Kovach et al, 1992
Environment	Environment			Z = bee toxicity	Kovach et al, 1992
Environment	Environment			B = beneficial arthropod toxicity	Kovach et al, 1992
Environment	Environment			P = plant surface half-life	Kovach et al, 1992
Environment	Environment			D = bird toxicity	Kovach et al, 1992
Environment	Environment		**Field Use EIQ - FEIQ**	FEIQ = EIQ x % Active Ingredient x Dosage Rate	Kovach et al. 1992, Sharma at al. 2015, FAO 2008, OECD 2014, Leach and Mumford, 2011; Rakesh et al., 2015; Waldener et al., 2011

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Category of indicator	Impact/ aspect assessed	Environment matrix	(Composed) indicator	Indicators	Source
Environment	Environment			% Active Ingredient	Kovach et al. 1992, Sharma at al. 2015, FAO 2008, OECD 2014, Leach and Mumford, 2011; Rakesh et al., 2015; Waldener et al., 2011
Environment	Environment			Pesticide dosage rate	Kovach et al. 1992, Sharma at al. 2015, FAO 2008, OECD 2014, Leach and Mumford, 2011; Rakesh et al., 2015; Waldener et al., 2011
Energy	Energy		**Energy efficiency**		
Energy	Energy			Inputs (labour, fuel, fertilizers and so on)	Reganold et al., 2001
Energy	Energy			Output (yield)	Reganold et al., 2001
Energy	Energy			Output/input ratios (energy efficiency)	Reganold et al., 2001
Environment	Environment		**Aquatic risk**		Cruzeiro et al, 2016
Environment	Environment	surface water		Pesticide concentration in water surface	Cruzeiro et al, 2016
Environment	Environment	surface water		Acute exposure	Cruzeiro et al, 2016
Environment	Environment		**Soil quality index**		
Environment	Environment	soil		Accommodate water entry	Reganold et al., 2001

Category of indicator	Impact/ aspect assessed	Environment matrix	(Composed) indicator	Indicators	Source
Environment	Environment	soil		Facilitate water movement and availability	Reganold et al., 2001
Environment	Environment	soil		Resist surface structure degradation	Reganold et al., 2001
Economic	Economic			Sustain fruit quality and productivity	Reganold et al., 2001
Environment	Organisms		**Pesticide contamination**		
Environment	Organisms	soil		Enzyme activities	Floch et al., 2011
Performance	Economic		**Horticultural performance**		
Performance	Economic			Crop yields	Reganold et al., 2001
Performance	Economic			Crop size	Reganold et al., 2001
Performance	Economic			Leaf and fruit mineral contents	Reganold et al., 2001
Performance	Economic			Crop grade	Reganold et al., 2001
Performance	Economic			Plant growth	Reganold et al., 2001
Performance	Economic			Leaf and crop mineral contents	Reganold et al., 2001
Performance	Economic			Crop maturity	Reganold et al., 2001
Performance	Consumer preference			Consumer taste preference	Reganold et al., 2001; Elliott and Mumford, 2002
Energy	Energy		**Energy efficiency**	Output/input ratios	Reganold et al., 2001

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Category of indicator	Impact/ aspect assessed	Environment matrix	(Composed) indicator	Indicators	Source
Energy	Energy			Labour	Reganold et al., 2001
Energy	Energy			Fuel	Reganold et al., 2001
Energy	Energy			Fertilizers	Reganold et al., 2001
Energy	Energy			Yield	Reganold et al., 2001
Environment	Environment		**Groundwater contamination**		
Environment	Environment	Soil		Depth of soil profile	Lindahl and Bockstaller 2012
Environment	Environment	Soil		FOC (topsoil organic carbon content)	Lindahl and Bockstaller 2012
Environment	Environment	Soil		Stoniness	Lindahl and Bockstaller 2012
Environment	Environment	Soil		DT50 (degradation half-life of pesticide	Lindahl and Bockstaller 2012
Environment	Environment	Soil		Koc (soil organic carbon)	Lindahl and Bockstaller 2012
Environment	Environment	Soil		Topsoil texture	Lindahl and Bockstaller 2012
Environment	Environment	Soil		Subsoil texture	Lindahl and Bockstaller 2012
Environment	Environment	Soil		Tillage	Lindahl and Bockstaller 2012
Environment	Environment	Soil		Season of application	Lindahl and Bockstaller 2012
Environment	Environment	Soil		Climatic zone	Lindahl and Bockstaller 2012
Environment	Environment		**Environmental Yardstick EYP**		
Environment	Environment	Groundwater		Groundwater contamination	Reus et al. 2002

Category of indicator	Impact/ aspect assessed	Environment matrix	(Composed) indicator	Indicators	Source
Environment	Environment	Surface water		Surface water (toxicity to water (LC50))	Reus et al. 2002
Environment	Environment	Soil		Soil (Persistence in soil (DT50)	Reus et al. 2002
Environment	Environment	Soil		Mobility in soil (expressed in Koc or Kom)	Reus et al. 2002
Environment	Environment	Organisms		Soil organisms (NOEC)	Reus et al. 2002
Environment	Environment		**HD**		
Environment	Environment	Groundwater		Groundwater contamination	Reus et al. 2002
Environment	Environment	Surface water		Toxicity in water (LC50)	Reus et al. 2002
Environment	Environment	Soil		Persistence in soil (DT50)	Reus et al. 2002
Environment	Environment	Soil		Mobility in soil (expressed in Koc or Kom)	Reus et al. 2002
Environment	Environment	Soil		Soil organisms (NOEC)	Reus et al. 2002
Environment	Environment	Surface water	**SYNOPS 2**	Toxicity in water (LC50)	Reus et al. 2002
Environment	Environment	Soil		Persistence in soil (DT50)	Reus et al. 2002
Environment	Environment	Soil		Mobility in soil (expressed in Koc or Kom)	Reus et al. 2002
Environment	Environment	Soil		Soil organisms (NOEC)	Reus et al. 2002
Environment	Environment	Air		(Air)	Reus et al. 2002

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Category of indicator	Impact/ aspect assessed	Environment matrix	(Composed) indicator	Indicators	Source
Environment	Environment		**Environmental performance indicator of pesticides - p-EMA**	Groundwater contamination	Reus et al. 2002
Environment	Environment	Surface water		Toxicity in water (LC50)	Reus et al. 2002
Environment	Environment	Soil		Persistence in soil (DT50)	Reus et al. 2002
Environment	Environment	Soil		Mobility in soil (expressed in Koc or Kom)	Reus et al. 2002
Environment	Environment	Soil		Soil organisms (NOEC)	Reus et al. 2002
Environment	Environment	Air		(Air)	Reus et al. 2002
Environment	Environment		**Pesticide environmental impact indicator - Ipest**		
Environment	Environment	Groundwater		Groundwater contamination	Reus et al. 2002
Environment	Environment	Surface water		Surface water (toxicity to water (LC50))	Reus et al. 2002
Environment	Environment	Air		Air	Reus et al. 2002

Category of indicator	Impact/ aspect assessed	Environment matrix	(Composed) indicator	Indicators	Source
Environment	Environment		**Environmental potential risk indicator for pesticides - EPRIP**		
Environment	Environment	Groundwater		Groundwater contamination	Reus et al. 2002
Environment	Environment	Surface water		Surface water (toxicity to water (LC50))	Reus et al. 2002
Environment	Environment	Soil		(Soil)	Reus et al. 2002
Environment	Environment	Air		(Air)	Reus et al. 2002
Environment	Environment		**System for predicting the environmental impact of pesticides - SyPEP**		
Environment	Environment	groundwater		Groundwater contamination	Reus et al. 2002
Environment	Environment	surface water		Surface water (toxicity to water (LC50))	Reus et al. 2002
Environment	Environment		**Pesticide environmental risk indicator - PERI**		
Environment	Environment	groundwater			Reus et al. 2002

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Category of indicator	Impact/ aspect assessed	Environment matrix	(Composed) indicator	Indicators	Source
Environment	Environment	soil			Reus et al. 2002
Environment	Environment	air			Reus et al. 2002
Environment	Environment		**Environmental Sustainability Index (ESI) and**		
Environment	Environment	soil		Soil productivity	Sands and Podmorea, 2000
Environment	Environment	groundwater		Groundwater availability	Sands and Podmorea, 2000
Environment	Environment			Potential to degrade the surrounding environment	Sands and Podmorea, 2000
Environment	Environment	soil		Topsoil depth (TS)	Sands and Podmorea, 2000
Environment	Environment	soil		Soil organic carbon (OC)	Sands and Podmorea, 2000
Environment	Environment	water		Total available water capacity (AW)	Sands and Podmorea, 2000
Environment	Environment			Bulk density (BD)	Sands and Podmorea, 2000
Environment	Environment	groundwater		Groundwater resource sub-index (GW)	Sands and Podmorea, 2000
Environment	Environment		**Hazard assessment**		
Environment	Environment	surface water		Persistence in fresh water	Tsaboula et al., 2016
Environment	Environment	surface water		Persistence in water-sediment	Tsaboula et al., 2017

Category of indicator	Impact/ aspect assessed	Environment matrix	(Composed) indicator	Indicators	Source
Environment	Environment	organisms		Bioaccumulation	Tsaboula et al., 2018
Environment	Environment	organisms		Toxicity	Tsaboula et al., 2019
Environment	Environment	organisms		Endocrine Disruption Potential	Tsaboula et al., 2020
Cost	Environment		**Total externality costs - PEA**		
Cost	Environment	drinking water		Pesticides in sources of drinking water	Leach and Mumford, 2008
Cost	Environment	organisms		Pollution incidents, fish deaths and monitoring costs	Leach and Mumford, 2008
Cost	Environment	organisms		Biodiversity/wildlife losses	Leach and Mumford, 2008
Cost	Social			Cultural, landscape, tourism, etc.	Leach and Mumford, 2008
Cost	Environment	organisms		Bee colony losses	Leach and Mumford, 2008
Cost	Health			Acute effects of pesticides to human health	Leach and Mumford, 2008
Cost	Environment		**Total externality costs - PEA**		
Cost	Health			Applicator effects	Leach and Mumford, 2011
Cost	Health			Picker effects	Leach and Mumford, 2011
Cost	Health			Consumer effects	Leach and Mumford, 2011
Cost	Environment	groundwater		Ground water	Leach and Mumford, 2011

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Category of indicator	Impact/ aspect assessed	Environment matrix	(Composed) indicator	Indicators	Source
Cost	Environment	surface water		Aquatic effects	Leach and Mumford, 2011
Cost	Environment	organisms		Bird effects	Leach and Mumford, 2011
Cost	Environment	organisms		Bee effects	Leach and Mumford, 2011
Cost	Environment			Beneficial species effects	Leach and Mumford, 2011

An interactive version of this table in Excel is available on the EUCLID project website.

From the long list of indicators evident in the literature a short list of dimensions is provided in Table 3 that encompasses the range found. These cover elements identified within categories of Efficacy, Cost, Environment, Health, Consumer preference and Social (Management). Policy issues could be related to any of these, depending on the orientation of the policy concerned.

Table 3. A short list of eleven EUCLID example indicator dimensions for IPM measures.

- Performance (efficacy)
- Safety - applicators
- Cost
- Environment
- Energy
- Options value
- Market standards
- Health – consumers
- Time (spent in carrying out the measure)
- Management effort (planning, overseeing, etc)
- Independence of measure from actions of other managers

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2. Indicator metrics

Table 4 shows some example metrics relevant to the short list of indicators from Table 3.

Table 4. Indicators and example metrics relevant to end-users of specific IPM measures.

Indicator	Example metrics
Performance	% kill of target pest organism
Safety - applicators	Mammalian toxicity LD_{50}
Cost	€/ha/use
Environment	Pesticide Environmental Accounting (PEA) metrics (Leach and Mumford, 2008) Applicator effects Picker/harvester effects Consumer effects Ground water contamination Aquatic species effects Bird effects Bee effects Beneficial species effects
Energy	KJoules/ha/use
Options value	Index of limitation/opportunity
Market standards	Maximum residue level (MRL) standards, cosmetic standards, good agricultural practice (GAP) standards
Health – consumers	Maximum residue limit MRL, harvest interval
Time (spent in carrying out measure)	Man-hours
Management effort (planning, overseeing, etc)	Man-hours, specific skills or training
Independence of measure from other managers	Management unit size needed for effective implementation of measure

Table 5 shows examples of higher level indicators that may be of more relevance for policy decisions. Economic indicators include aggregate costs at a national or regional level (Leach and Mumford, 2008; Leach and Mumford 2011). The Community level represents impacts on people on and near the farm. Environmental metrics include aggregate incidents or losses, or physical properties of pesticides (either those used or those replaced by other measures).

Table 5. Example high level indicators, dimensions and metrics.

Indicators	Dimensions	Metrics
Economic	Economic	Crop value per ha
Economic	Economic	Implementation cost per total crop area
Economic	Economic	Pest monitoring cost
Economic	Economic	Pesticide monitoring cost
Community	Economic	Tourism loss
Community	Efficiency	Field use quantity in total for aggregate crop
Community	Toxicity	Field use active ingredient (kg/yr) quantity weighted by toxicity
Community	Health Risk	Picker/harvester health effects
Community	Health Risk	Pesticide levels in drinking water
Environment	Risk	Pollution incidents per year
Environment	Run-off	Leaching ability
Environment	Run-off	Surface loss potential
Environment	Toxicity	Fish death
Environment	Toxicity	Biodiversity/wildlife losses
Environment	Toxicity	LD_{50} for beneficial insects
Environment	Toxicity	Bee colony loss
Environment	Toxicity	Mammalian acute dermal toxicity
Environment	Toxicity	Chronic mammalian toxicity
Environment	Toxicity	Formulation concentration
Environment	Toxicity	Field application rate active Ingredient (kg/yr) weighted by toxicity
Consumer	Toxicity	Maximum residue level for retail produce
Consumer	Appearance	Blemishes, surface irregularity, market grade, price

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3. Indicators by category of IPM measure

The pest management solutions being developed within the EUCLID project can be categorised as shown in Table 6.

Table 6. EUCLID pest management measures.

- Pesticides (including botanicals)
- Varieties
- Cultivation (including associated crops/non-crop hosts supporting biocontrol)
- Rotation
- Biocontrol/conservation (including entomo-vectoring)
- Physical barriers
- Pheromones
- Sterile insect technique (SIT)
- Crop timing
- Bio-stimulation (including RNAi, resistance induction)

In Table 7 relevant indicators from the short list (from Table 3) are presented within each category of IPM measure (from Table 3). Conventional control using pesticides is effectively the baseline for comparison for any other measures, so all the indicators are shown for pesticides. For the other measures shorter lists of the most relevant specific indicators are shown. Marginal differences in indicator values would be used in comparisons of actions.

Table 7. Categories of IPM measures and indicators.

Pesticides

- Performance
- Safety - applicators
- Cost
- Environment
- Energy
- Market standards
- Health – consumers
- Independence
- Options
- Management effort
- Time

Varieties

- Performance
- Market standards
- Options

Cultivation

- Performance
- Energy
- Cost
- Time
- Environment

Rotation

- Performance
- Options
- Management effort

Biocontrol

- Performance
- Cost
- Market standards
- Options
- Environment
- Management effort

Physical barriers

- Performance
- Energy
- Cost
- Management effort

Pheromones

- Performance
- Cost
- Market standards
- Management effort

Crop timing

- Performance
- Options
- Management effort

SIT

- Performance
- Cost
- Market standards
- Options
- Environment
- Management effort

Bio-stimulation

- Performance
- Cost
- Options
- Market standards
- Environment
- Management effort

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4. Matrix for technology/technique assessment

Table 8. Matrix of measures and indicators with example metrics.

	Pesticides	Varieties	Cultivation	Rotation	Biocontrol	Physical barriers	Pheromones	Timing	SIT	Bio-stimulation
Performance	Pest load/ha	Pest load/ha	Pest load/ha	Pest load/ha	Pest load/ha	Pest load/ha	Pest load/ha	Pest load/ha	Pest load/ha	Pest load/ha
Safety - applicators	LD_{50} toxicity to harvesters									LD_{50} toxicity to harvesters
Cost	Cost/ha	Cost/ha	Cost/ha	Cost/ha	Cost/ha	Cost/ha	Cost/ha	Cost/ha	Cost/ha	Cost/ha
Energy	kJ/kg production kJ/ha application		Fuel/ha	Fuel/ha	kJ/kg production kJ/ha application	kJ production kJ/ha application	kJ production kJ/ha application		kJ/kg production kJ/ha application	kJ production kJ/ha application
Environment	Leaching potential LD_{50} toxicity to non-targets		Conserved beneficial species Soil disturbance	Biodiversity	Biodiversity			Biodiversity		Biodiversity
Market standards	Appearance quality Maximum Residue Level Production practice list	Product value/kg		Market options for rotation crops	Appearance quality		Appearance quality	Market window	Appearance quality	Appearance quality
Health - consumers	LD_{50} Humans Maximum Residue Level									LD_{50} Humans Maximum Residue Level
Option effects	Biocontrol compatible SIT compatible		Conservation biocontrol compatible	Conservation biocontrol compatible	Pesticides compatible	Conservation biocontrol compatible		Biocontrol compatible	Pesticide compatible	Biocontrol compatible
Time	Hours/ha Specific timing	Hours/ha	Hours/ha Specific timing	Hours/ha	Hours/ha Specific timing	Hours/ha	Hours/ha Specific timing	Hours/ha Specific timing	Hours/ha Specific timing	Hours/ha Specific timing
Management effort	Skill/training Planning Equipment	Skill/training Planning	Skill/training Planning Equipment	Skill/training Planning Equipment	Skill/training Planning	Skill/training Planning Equipment	Skill/training Planning Equipment	Skill/training Planning	Skill/training Planning Equipment	Skill/training Planning Equipment
Independence	Drift prevention			Pest reservoir scale			Area-wide scale	Irrigation or other restrictions	Area-wide scale	

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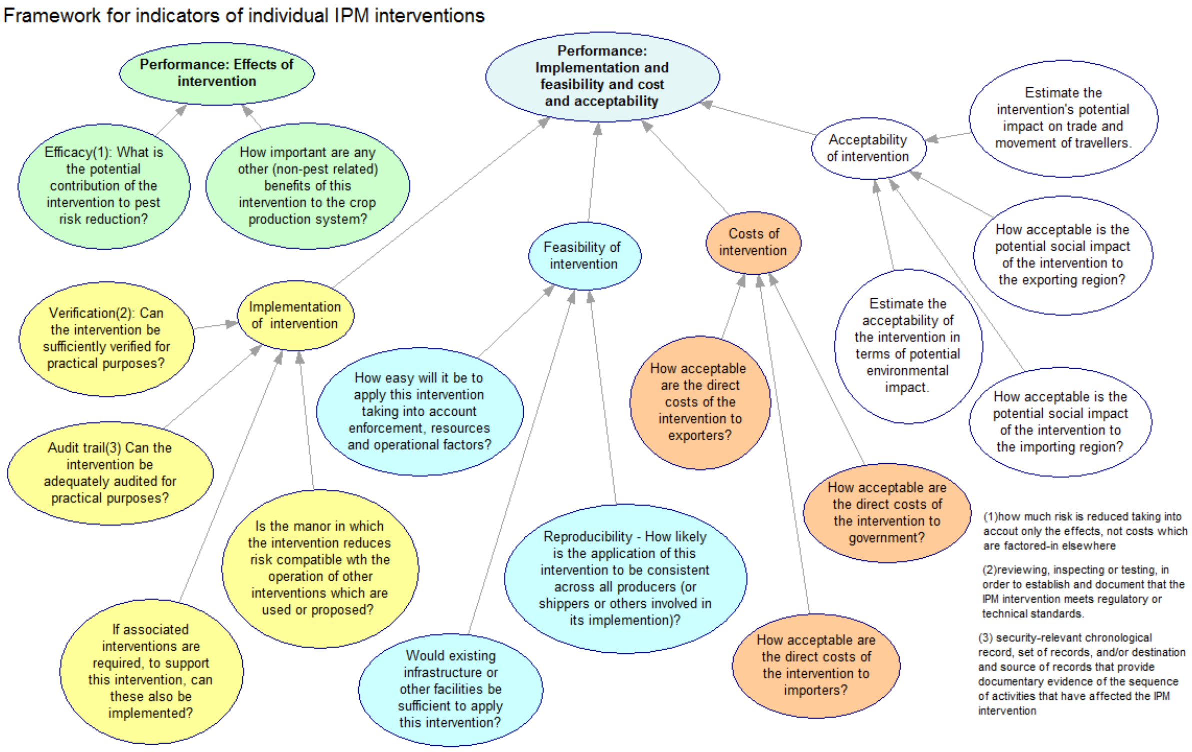
5. Framework for indicators

Indicators can be clustered into two high level dimensions that describe their performance in terms of direct effects in their use environment and their uptake potential. This concept is illustrated in Figure 1.

Figure 1. Framework for indicators in terms of Efficacy and Uptake. Efficacy effects occur at both farm and consumer levels. Uptake feasibility occurs at the farm level and potentially at a wider regional level for area-wide or regulated control actions, with costs and aspects of acceptability that may extend to farm, consumer and governments. The figure can apply to both internationally traded produce and domestic production and supply chains.



The above figure is a network in which the aspects of a pest management intervention are clustered according to: efficacy (direct and indirect); uptake (implementation, feasibility, cost and acceptability). The network is set out in such a way that there are two measures of intervention performance (at the top of the diagram) in which efficacy is kept separate from the other aspects of performance because, depending on the cost or effort related to uptake aspects, an intervention may be valuable even if its contribution to pest reduction is quite small. So, for example, a measure with only marginal improvement in efficacy may still be implemented if it is easy, cheap, and acceptable.

The network itself, and the wording of questions concerning the different aspects, are constructed in such a way that the diagram can be translated into a Bayesian Network, in which probability distributions of performance can be modelled (Quinlan et al., 2016). Using such a network it would be possible to integrate the evidence and beliefs about each aspect to provide an overall measure of the expected outcomes of intervention performance. This would allow consistent comparison of pest management measures which are either in use, of potential use, under development or proposed.

Indicators can be used to express performance in terms of efficacy and uptake at each stage of production where pest management measures are applied to a crop system (Quinlan et al., 2016). This can be organised through a production chain (Figure 2). Each measure in such a chain would have specific relevant indicators, for both efficacy and uptake.

Figure 2. An example Production Chain, illustrating pest management measures applied to stages throughout a production system.

At the policy level, IPM measures can be placed in a framework such as the DPSIR framework (Smeets and Weterings, 1999). This describes Drivers, Pressures, States, Impacts and Responses in a dynamic relationship that helps to describe, organise and predict change in a continuously evolving cycle (Figure 3).

Figure 3. The basic DPSIR cycle.

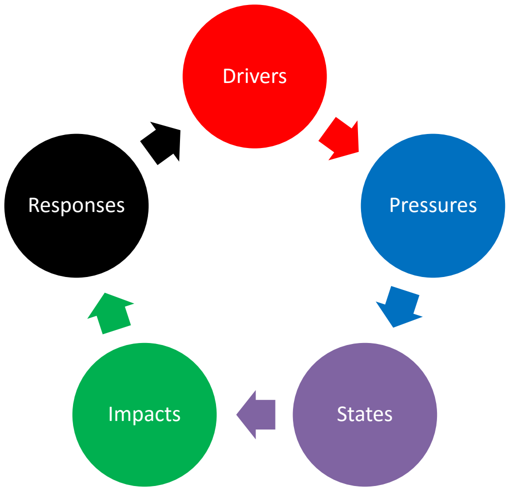


Figure 4 illustrates an example of how a DPSIR framework can show a series of steps leading to an opportunity or necessity for change in response, the black series for an existing pest and the red series for a new introduction. There may be continuous or threshold pressures, states and impacts, and continuous or step changes in responses.

Figure 4. Example Driver/Pressure/State/Indicator/Response analysis.

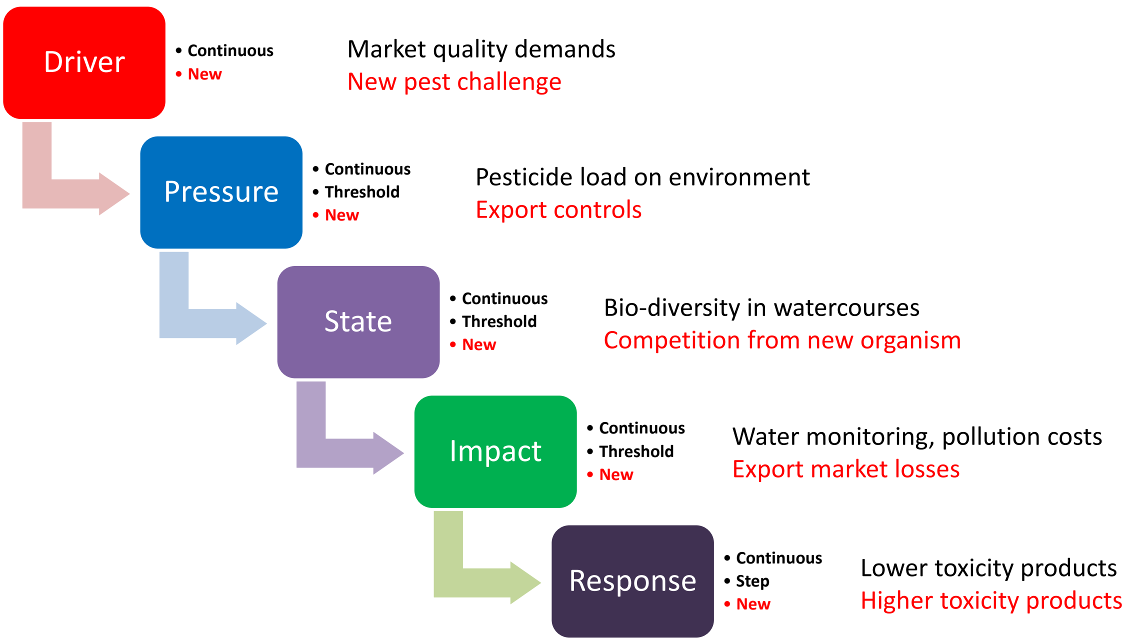
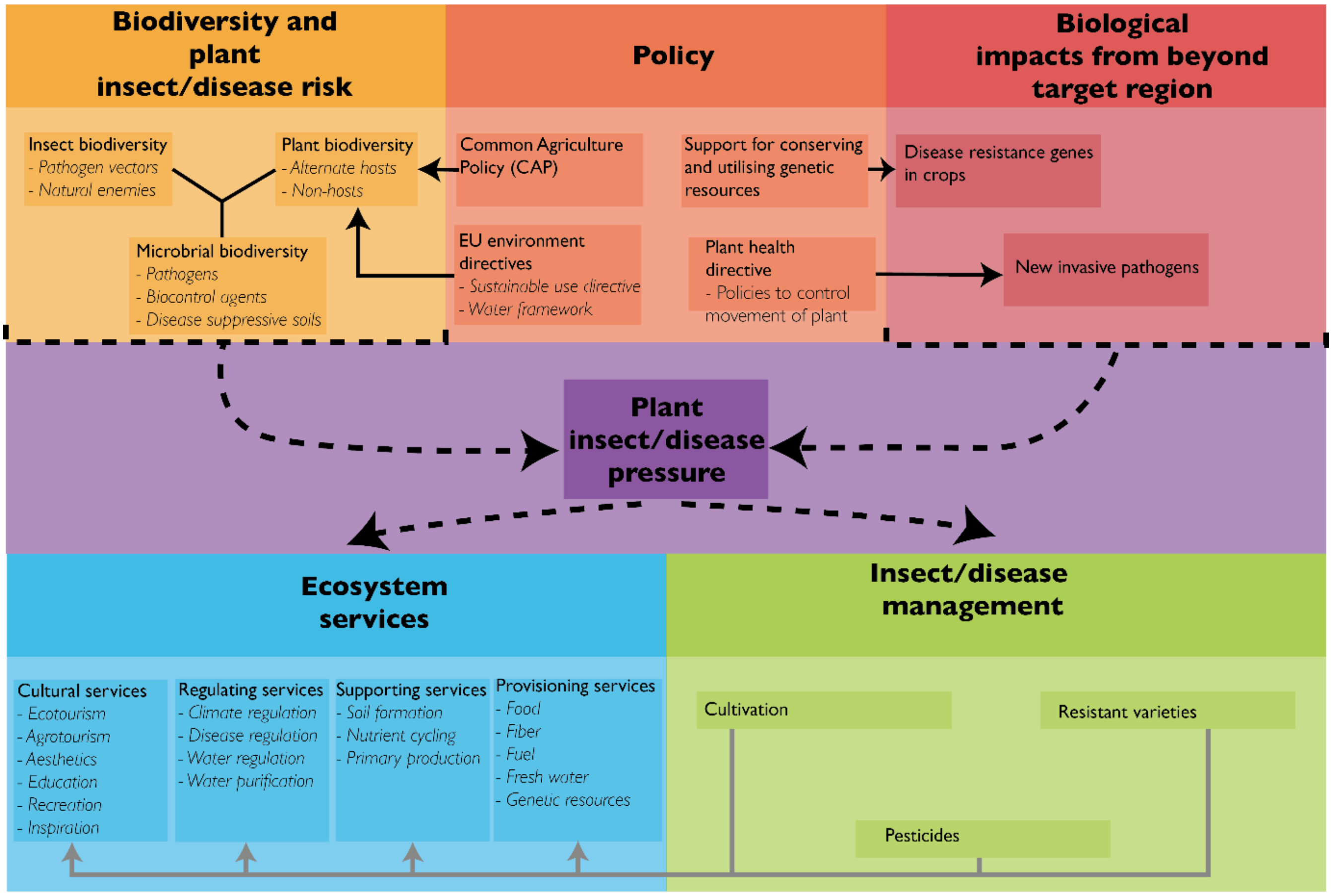


Figure 5 provides another illustration of the potential relationships between various drivers of pest status and impacts on ecosystems services and farm and policy level responses. The various components of ecosystems services listed in the figure offer potential indicators related to outcomes of pest management or policies related to pest management. The four types of ecosystems services and their components do not have clear intrinsic weights, so their importance will vary depending on the case. This is a common issue for complex multi-dimensional indicators, since there are no universal weightings for different elements.

Figure 5. Modified figure on ecosystems services impacts, and drivers and pressures for pest management (adapted from Cheatham et al., 2009).



6. Conclusion

A substantial body of literature is available in which indicators for IPM measures are described. Some indicators have very specific metrics while others do not have well-defined metrics. Conventional pest management practice provides a baseline for comparison with novel technologies or techniques. The most common demand for new solutions comes through pressure to replace or reduce pesticides, so the indicators for pesticides are most likely to be the reference baseline.

Several hundred indicators are listed. These are categorised in hierarchical lists that cover different dimensions, such as economics, community, environment and consumers. A summary matrix of ten classes of pest management measures and a list of eleven broad indicator dimensions demonstrates example metrics that are likely to be relevant for various combinations.

Some frameworks for using indicators are illustrated. These include a conceptual ontology describing efficacy and uptake as primary indicators, the production chain approach to systematically model measures through a production cycle, and the DPSIR framework to describe cause and effect relationships that explain change in a system.

Developers, potential users of pest management measures and other stakeholders will need to identify specific indicators that are relevant to the particular measures and objectives related to each pest threat. No single indicator is available to fully represent the effects of any measure, because of the diverse dimensions that are relevant. Some composite indicators have been identified, but even these do not cover the full spectrum of issues. Most composite indicators in the literature reviewed relate to the complex environmental impacts of pesticides.

Glossary

DPSIR	Drivers. Pressures, States, Impacts, Responses – a relational framework
EIQ	Environmental Impact Quotient
IMPERIAL	Imperial College London
IPM	Integrated Pest Management, a combination of methods to achieve pest control efficiently
PEA	Pesticide Environmental Accounting
RNAi	Ribonucleic Acid (RNA) Interference, a biological process in which RNA molecules inhibit gene expression
SIT	Sterile Insect Technique, release of sterile insects to control pest species
VIU	Venice International University

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