A System Dynamic Model of Water-Land-Food-Energy-Ecosystem-Environment-Economic-Social Nexus for Western Lake Erie Basin-USA

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Abstract

The concept of water-food-energy nexus has been widely studied in the past decade. In this paper we expand on this concept to Water-Food-Land-Energy-Ecosystem-Environment Nexus with economic and social aspects based on the life cycle assessment thinking. Set of Environment Footprint Assessment (EFA), Life Cycle Assessment (LCA), and Socio-Economic Assessment (SEA) indicators are proposed to apply this approach. Decision Support System for Water-Land-Food-Energy-Ecosystem-Environment-Economic-Social nexus (SD-WLF4ES-Nexus) applying system dynamic model approach for simulating this tackle is utilized. SD-WLF4ES-Nexus is applied to predict the WLF4ES nexus of one of the main crop, corn crop, in twenty counties located in Western Lake Erie Basin (WLEB) in USA for the period 2016-2030. The prediction is based on scenarios for population, planted and harvested land, and yield, crop production use by segments, and crop production costs and returns. A matrix for WLF4ES nexus of corn crop in WLEB is developed. This matrix can help in developing polices and strategies for managing the nexus in the basin.

1. Introduction

As our society understands the interconnectedness of resources, management approaches are gradually shifting from individually managing different resources to managing the individual resources as well as their causal links. This new understanding first arose from the water-energy nexus [Schnoor 2011] and gradually shifted to food-energy-water nexus [Bonn 2011, Hoff 2011, FAO) 2014, Allen et al. 2015, Reddy et al. 2018, Jarvie et al. 2015, Karabulut et al. 2018].

Many authors also explored expanding the food-energy-water nexus to include other concepts such as the climate [Boelee et al. 2011(a), Field and Michalak 2015, Liu 2016, El-Gafy 2017(a), El-Gafy et al. 2017(b)], land [Song 2017], environment [Boelee et al. 2011(a), McCornick et al. 2008, Grenade et al. 2016, Salmoral and Yan 2018], ecosystem services [Boelee et al. 2011(b), Hurford and Harou 2014, Rasul 2014, Karabulut et al. 2015, Liu 2016, Liu et al. 2017, Bell et al. 2016], and social and economic sustainability [FAO 2014, El-Gafy et al. 2017(b), Schlör et al. 2018], and life cycle assessment [Al-Ansari et la. 2015, Karabulut et al. 2018].

The previous studies showed that nexus challenges are unique for each case. The modeling approaches also varied across studies in terms of water resources (surface, ground, desalination), energy resources (fuel, electricity, renewable, bioenergy, solar, wind) and scale of analysis (global, national, local). The previous developed tools have progressive modeling proficiency for the nexus. However, none of the previous studies model the dynamic integration of the environment, social, and economic impact of agricultural management strategies on the water-food-land-energy-ecosystem services through the entire life cycle of the crop production system in holistic manner. In this study, we built upon the prior work by creating a system dynamic tool for Water-Land-Food-Energy-Ecosystem-Environment-Economic-Social nexus (SD-WLF4ES-Nexus) that incorporated different scenarios for population and crop production variability for the Western Lake Erie Basin (WLEB) of USA. WLEB has twenty counties in the State of Ohio.

WLEB was selected as the study site because more than 70 % of WLEB is used for agriculture both for food and bioenergy production and these activities are primary contributors to non-point source pollution in Lake Erie ultimately resulting in eutrophication and harmful algal blooms (HABs). While eutrophication, HABs, and nutrient management in WLEB has been widely studied [Scavia et al. 2014, Scavia et al. 2016, Scavia et al. 2017, Ohio Lake Erie Phosphorus Task Force 2010, Ohio Lake Erie Phosphorus Task Force 2013, IJC 2014, Scavia et al. 2016], a system level understanding of the different indicators for the area has been missing. Also, it has been suggested that the policies should consider an integrated approach that links food, energy, water systems [Jarvie et al. 2015].

Our study addressed this suggestion by quantifying these and additional environmental, economic, and social systems in a comprehensive manner by addressing two research questions: i) what are the current WLF4ES indicators of the corn agricultural system for WLEB? and ii) how will these indicators change in the future as a result of expected changes in population, percentage crop area and yield, different uses of corn and corn production costs and returns?

2. Methodology

The study was conducted in three phases. First, we developed indicators for the WLF4ES nexus related to environment footprint assessment (EFA), social and economic assessment (SEA), and life cycle assessment (LCA). We then modified an existing food–energy-water-land nexus system dynamic model (El-Gafy et al 2017) to include the environment, economic, social, and ecosystem indicators. The sub-models of the new model DSS [SD-WLF4ES-Nexus] and there related equations are shown in the Supplementary Information.

Ultimately, SD-WLF4ES-Nexus are consists of eight sectors: land footprint, crop production, water footprint, energy footprint, fertilizer footprint (including N and P loads), life cycle environmental impacts, economic impacts, and social impacts. We populated the model with WLEB specific data for corn production. For many of the parameters, data were input and analyzed at the county level including the 20 Ohio counties that located in WLEB: Allen, Defiance, Fulton, Hancock, Henry, Lucas, Paulding, Putnam, Van Wert, William, wood, Crawford, Erie, Ottawa, Sandusky, Seneca, Wyandot, Auglaize, Hardin, and Mercer counties. SD-WLF4ES-Nexus was applied to predicted WLF4ES nexus in WLEB for the period 2016–2030 based on estimated scenarios for population, planted and harvested land, and yield, crop production use by segments, and crop production costs and returns.

3. Results And Discussion

3.1 Indicators for amalgamating WLF4ES nexus

The proposed indicators for amalgamating WLF4ES nexus of a crop are illustrated in Fig. 1. They include Environment Footprint Assessment (EFA), Life Cycle Assessment (LCA), and Socio-Economic Assessment (SEA) based indicators. EFA are resource use and emissions oriented indicators while LCA and SEA are impact oriented indicators [Davy et al. 2019]. The EFA indicators (land and its associated labours, fertilizers, pesticides, water, energy, and cost inputs) represent the inputs for cultivating system of the crop. The LCA and SEA indicators represent the impacts of the cultivation system. The LCA indicators includes P and N loads to water bodies and the midpoint environmental impacts calculated using TRACI life cycle impact assessment (LCIA) model [Bare 2011]. These TRACI impact categories address ecosystem quality (global warming, ozone depletion, smog, acidification, eutrophication, eco-toxicity), human health (carcinogenic, non-carcinogenic and respiratory effects), and the resource depletion (fossil fuel depletion). The SEA indicators include crop production (food, feed, bioenergy, export and stock), economic (crop revenue and its economic productivity of water and energy), and social (food per capita, number of labours, and the mass productivity of water and energy) impacts.

3.2 Scenarios for the expected changes in WLF4ESN

The model was applied for a period of 2016–2030. Data in Table 1 were used to linearly change the population, crop area % and yield % by county from year to year. Corn produced in WLEB is stocked or exported or it may be used for different purposes such as ethanol and byproducts, human food, and animal feed. Data in Table 2 were used to linearly change crop production use by segment. Data in Table 2 were also used to linearly change corn production costs and returns for the 20 counties.

Table 1
Applied scenarios for population, planted and harvested land, and yield yearly grows rates of corn at the 20 counties

County	Population % [1]	Crop area %[2]		Yield %[2]
		Planted	Harvested	
Allen	-0.41	1.36	-0.43	1.69
Defiance	-0.31	0.41	0.33	1.62
Fulton	-0.13	-0.16	-0.01	0.13
Hancock	0.18	1.31	1.47	1.81
Henry	-0.51	1.17	1.58	0.22
Lucas	-0.34	0.80	0.90	0.68
Paulding	-0.55	2.45	2.32	1.40
Putnam	-0.25	0.92	0.91	1.92
Van Wert	-0.25	1.34	1.54	1.24
William	-0.32	1.27	1.20	1.11
Wood	0.54	0.69	0.75	0.95
Crawford	-0.66	0.61	0.67	1.90
Erie	-0.41	5.83	-1.02	0.81
Ottawa	-0.26	-2.53	-2.40	1.03
Sandusky	-0.40	0.81	1.08	1.05
Seneca	-0.37	1.13	1.31	2.14
Wyandot	-0.36	1.53	1.67	1.34
Auglaize	-0.05	0.99	0.98	2.41
Hardin	-0.30	1.49	1.18	1.24
Mercer	0.02	0.96	0.64	2.32

[1] Collected data for annualized percent change of population for the period 2010 to 2017 for each county, source of data (ODSA, 2019). [2]Estimated scenarios applying CAGR methods based on historical data for the period (2006–2016) for each county, source of data (USDA, 2019a).

Table 2
Applied scenarios for yearly change rates of corn production use by segments and its production costs and returns %

Crop production use by segments %[1]		Corn production costs and returns %[2]					
		Gross value of production		Operating costs		Allocated overhead	
Ethanol and by-products	-0.064	Primary product grain	+ 0.010	Seed	+ 0.022	Hired labor	+ 0.073
Food	+ 0.084	Secondary product silage	+ 0.033	Fertilizer	-0.014	Opportunity cost of unpaid labor	+ 0.014
Feed	+ 1.231			Chemicals	+ 0.013	machinery and equipment	+ 0.041
Export	-0.376			Custom services	+ 0.074	Opportunity cost of land	+ 0.028
Stock	+ 0.124			Fuel and electricity	+ 0.011	Taxes and insurance	+ 0.040
				Repairs	+ 0.080	General farm overhead	+ 0.024
				Irrigation water	NA		
				Interest on operating capital	+ 0.210		

[1] Estimated scenarios applying CAGR methods based on U.S. corn long term projection for (2016–2027), Source of data (USDA,2018). [2] Estimated scenarios applying CAGR methods based on historical data (2006–2016) for U.S. and regions, Source of data (USDA, 2019b)

3.3 Current and long-term projection of WLF4ES nexus in WLEB and its counties

SD-WLF4ESN model simulates the yearly WLF4ES nexus of the twenty deliberate counties for the period 2016–2030 based on the scenarios illustrated in Table 1 and Table 2. The corn's WLF4ES Nexus in WLEB' counties for the years 2016 and 2030 is shown in Fig. 2 as example for these simulation. The yearly changes for each indicator are shown in annex (a-1). Yearly matrixes for the period 2016–2030 of amalgamating corn's WLF4ES Nexus in WLEB are developed. as An example for the output matrix of amalgamating corn's WLF4ES nexus in WLEB for years 2016 and 2030 is shown in Table 3.

SD-WLF4ESN projected the variation in WLF4ES nexus from 2016 to 2030 in WLEB as follows:

- Land footprint and its yield: The output of SD-WLF4ESN model for year 2016, as shown in Table 3 and Fig. 2, demonstrates that the corn planted and harvested LFP in WLEB was about 0.52 and 0.49 million ha respectively and its yield was 9.84 ton/ha. Based on the yearly growth rate of the planted and harvested areas of con and its yearly yield grows rate in the 20 counties, Table 1 and Fig. 2.a, the planted and harvested LFP of corn in WLEB in 2030 will be increased by about 19% and 13% respectively and the average corn yield will increase by about 2 ton/ha. The change in the corn planted and harvested area and its yield will result in altering the crop production, WFP, EFP, environment impact of each influence category, and corn production revenue as follows:
- Crop production: The total corn production from the 20 counties in the study area, Fig. 2.b, was about 4.9 million ton in 2016. Due to the increasing in the planted and harvested areas of corn and its yield in most of the 20 counties under study, the corn production in WLEB will be increased by about 2.02 million ton in 2030.

The crop production is assumed to be used by 35%, 10%, 38%, 10%, 7% for ethanol and by-products, food, feed, export, and stock respectively in 2016 in each county, Fig. 2.c. Due to the estimated scenarios for the crop production use by segments, Table 2, the crop use will vary in 2030 as follows.

- Food use: In 2016, the average food per capita in WLEB was about 610 kg/capita (based on the average food per capita in the 20 counties). The population in most of the studied counties will decrease, as shown in Fig. 2.c, meanwhile the crop production and the yearly food segment will be increased, as shown in Table 2. Therefore, the average food per capita in WLEB will be increased by about 300 kg/capita in 2030.
- Ethanol potential: In spite of the percentage of crop production use for ethanol will be decreased, as shown in Table 2, the ethanol potential will increase by 76 million gallon as a result of increasing the crop production in most of WLEB's counties
- Feed use: The feed segment have the heist increasing rate (+ 1.2%), Table 2. The quantity of corn production for feed segment will be increase from 1.85 million tons in 2016 to 3.1 million tons in 2030.
- Export use: In spite of the percentage of crop production use for export will be decreased (-0.38 %), as shown in Table 2, the corn exports from the study area is expected to be 0.64 million tons in 2030 comparing to 0.49 in 2016 due to in the quantity of the crop production in most of the counties in the study area.
- Water footprint (WFP): The total WFP of corn cultivation in the study area was about 87 BCM (consumption and pollution WFP) in 2016 based on the summation of WFP in the 20 counties, Fig. 2.d. The estimated consumption WFP (green and blue) was about 3 BCM. The total green water consumption footprint (2.9 BCM) was higher compared to the blue water consumption footprint (0.1 BCM) for corn production in all the 20 counties in WLEB, Fig. 2.e.

The corn pollution WFP, corn grey WFP, is about 84 BCM, based on the summation of grey WFP in the 20 counties, Fig. 2.f. The quantity of grey WFP is due to the application of 124 million ton of P and N nutrients to produce the 4.9 million ton of corn in the study area. The crop water consumption and pollution footprint will increase by about by 19.6 % and 18.9% respectively in 2030. In 2030, the total WFP of corn crop in the study area will increase to be 105 MCB.

The change in the pollution footprint (grey WFP) is due to the increasing of the fertilizer footprint. The GWF related to P loads is about 83.7 BCM (with P maximum allowable concentration and fraction natural concentration 0.01 and 0 mg/l respectively). The GWF related to N loads is about 0.63 BCM (with maximum allowable concentration and average leaching-runoff fraction natural concentration 12 mg/l and 0 mg/l). In 2030, P-related and N-related grey will be augmented to 99 BCM and 751 MCM respectively.

- Fertilizer footprint: (P and N footprint in 2016 was about 42 and 82 million ton respectively). In 2030, P and N footprint will be increased by 7 and 15 M ton respectively. P load will increase from 1.29 million ton in 2016 to 1.49 million ton in 2030. N load will increase from 8.2 million ton in 2016 to 9.7 million ton in 2030.
- Energy footprint (EFP): EFP of cultivating corn in 2016 was about 17,563 TJ. EFP will increase by about 18.9% in 2030. 53% of this EFP is related to the indirect use of energy for fertilizer production mainly for nitrogen production, Fig. 2h. The lowest increase will be in the energy consumption for irrigation that will be raised only by about 14% while the all other direct and indirect energy inputs will be raised by about 19%.
- Environment impact: Nitrogen fertilizers have the heist environment impact in the study areas, Fig. 2i. Nitrogen fertilizers is responsible about the potential of 77.73% global warming, 68.93%of smog, 63.30% of acidification, 60.94% of ecotoxicity, 53.94% of carcinogenic, 62.57% of non-carcinogenic, 44.17%, of respiratory effects, and 45.32% of fossil fuel depletion. Herbicides are responsible about the 27.98% of ozone depletion potential in the study area. In 2030, Environment impact of each influence category will be raised by about 26% due to the increase in the planted area and its associated energy, water, and agricultural fertilizer and pesticides inputs. The ecosystem service capacity will be the most disfigurement mainly due to the high increase in the eutrophication influence. The increase in eutrophication influence is resulting from the increase of P and N loads to the freshwater, as mentioned above.
- Economic impact: In 2030, the net farm return based on total value of corn production less operating costs in most of the 20 counties will increase, Fig. 2.j. This will result in growing the net farm return in WLEB by about $ 78 million more than its value in 2016. The increasing in the ethanol potential, as mentioned above, will resulting in increasing the contribution of the ethanol production to the economy of the study area from $ 263 million in 2016 to $369 million in 2030 assuming that the ethanol yield (110 gallons/ton) and price of ethanol (1.4 $/gallon) will not change. Mass and economic water productivity will increase from 5.64E-05 to 6.53E-05 ton /m^3 and from 1.44E-01 to 1.27E-01 \$/m^3 respectively. Mass and energy productivity will increase from 2.19E-04 to 2.64E-04 ton/MJ and from 1.83E-02 to 2.04E-02 $/MJ.
- Social impact: according to the social issue, the current research, as mentioned before, consider labour and economic and mass productivity of water and energy indicators. The labour force will increase by about 19%. Due to the increasing in the corn exports from the study area, the virtual water and energy through the crop trade will increase by about 1.18 BCM and 224 TJ respectively in 2030.

Table 3
Developed output matrix of amalgamating Corn's WLF4ES Nexus in WLEB (2016–2030)

Nexus parameter	Equa. No	Environment footprint family, economic, and life cycle impact assessment indicators								
LFP (ha)	Equ. 1 & 2		**Planted**	**Harvested**						
		2016	529,970	499,209						
		2030	630,085	568,935						
Crop production (M ton)	Equ. 3 to 6		**Production**	**Ethanol**	**Food**	**Feed**	**Export**	**Stock**		
		2016	4.87	1.70	0.49	1.85	0.49	0.34		
		2030	6.89	2.39	0.70	3.11	0.64	0.04		
WFP (MCM)	Equ. 8&9		**Total WFP**	**Green-WFP**	**Blue-WFP**	**Grey-WFP**	**P-R- GWFP**	**N-R-GWFP**		
		2016	87,402	2,890	89	84,423	83,791	632		
		2030	104,577	4,075	131	100,371	99,620	751		
EFP (TJ)	Equ. 10		**Total EFP**	**Diesel**	**Gasoline**	**Electricity**	**Irrigation**	**Fertilizer**	**Pesticides**	**Transportati**
		2016	17,563	2,225	898	75	21	7,536	1,997	375
		2030	20,880	2,645	1,068	90	24	8,959	2,374	446
Environment	Equ. 13 to 17	**Fertilizer footprint and loads to water body (M ton)**								
			P	**N**	**Potassium**	**Lime**	**P-Load**	**N-Load**		
		2016	41.87	82.15	44.52	593.57	1.26	8.21		
		2030	49.78	97.66	52.93	705.70	1.49	9.77		
		Environment Impact								
			Climate change		**Ecosystem service capacity**				**Human health**	
			Ozone depletion	G. warming	Smog	Acidification	Eutrophication	Eco toxicity	Carcinogenic	Non carcinogenic
			(kg CFC-11 eq)	(kg CO2 eq)	(kg O3 eq)	(kg SO2 eq)	(kg N eq)	(CTUe)	CTUh	CTUh
		2016	2.02E + 02	1.06E + 09	5.49E + 07	5.32E + 06	2.73E + 03	7.35E + 09	4.55E + 01	3.11E + 02
		2030	2.55E + 02	1.33E + 09	6.93E + 07	6.71E + 06	3.44E + 06	9.26E + 09	5.72E + 01	3.92E + 02
Economic	Equ. 18 to 22	**Economic impact (M $)**								
			Grain	**Silage**	**Gross value**	**Operation costs**	**Overhead**	**Total cost**	**Gross value less costs**	**Gross value less operatir costs**
		2016	846	1.20	847	437	480	917	-70	**410**
		2030	1007	1.44	1009	521	573	1094	-85	**487**
			Ethanol potential (million gallon)	Ethanol potential to economy (Million $)						
		2016	188	263						
		2030	263	369						
		Productivity								
			Land		**Water**		**Energy**			
			Mass (yield)	Economic	Mass	Economic	Mass	Economic		
			ton/ha	$/ha	ton/m3	$/m3	ton/MJ	$/MJ		
		2016	9.84	217	5.64E-05	1.44E-01	2.19E-04	1.83E-02		
		2030	11.87	307	6.53E-05	1.27E-01	2.64E-04	2.04E-02		

Nexus parameter	Equa. No	Environment footprint family, economic, and life cycle impact assessment indicators				
Social	Equ. 25 to 27		**Labour**	**Food** per capita	**Virtual WFP export**	**Virtual EFP export**
			hour	kg/capita	(MCM)	(TJ)
		2016	6,041,660	610	8,740	1,756
		2030	7,182,966	931	9,921	1,981

4. Conclusion

The research developed a conceptual framework for amalgamating WLF4ES nexus by proposing a set of EFA, SEA, and LAC indicators. The EFA indicators include land and its associated labours, fertilizers, pesticides, water, energy, and costs inputs). The SEA indicators for economic impact include the crop revenue and its economic productivity of water and energy. According to SEA indicators for the social impact are concentrated in food per capita, number of labours, and the mass productivity of water and energy. The LCA indicators includes P and N loads to water bodies and the potential midpoint environmental impacts that include the global warming potential (ozone depletion, smog), the ecosystem quality (smog, acidification, eutrophication, eco-toxicity), human health (carcinogenic, non-carcinogenic and respiratory effects), and the resource depletion (fossil fuel depletion).

A matrix that summarizes and quantifies the WLF4ES nexus of cultivating one hectare of corn in WLEB in year 2016 is presented. WLF4ES-Nexus of corn crop in twenty counties located in WLEB in USA for the period (2016–2030) is quantified, analyzed, and summarized in a developed matrix. The developed matrix illustrated that in 2030 the planted and harvested LFP of corn in will be increased by about 19% and 13% respectively and the average corn yield will increase by about 2 ton/ha. These changes will have its impact on the crop production, WFP, EFP, environment, economic and social scheme in the study area.

Due to the increasing in the planted and harvested areas of corn and its yield in most of the 20 counties under study, the corn production in WLEB will be increased by about 2.02 million ton in 2030. The average food per capita, the ethanol potential, and the quantity of corn production for feed segment will increase by about 300 kg/capita, 76 million gallon, and 1.25 million tons in 2030. The corn export from the study area is expected to be 0.64 million tons in 2030 comparing to 0.49 in 2016.

The consumption WFP (green and blue) and pollution WFP (grey) in 2016 of corn in the study area was about 3 BCM and 84 BCM respectively. In 2030, the consumption and pollution WFP will increase by about 19.6 % and 18.9%. P and N related grey WFP will be augmented from 84 BCM and 632 MCM in 2016 to 99 BCM and 751 MCM in 2030. EFP of cultivating corn in 2016 was about 17,563 TJ. EFP will increase by about 18.9% in 2030. 53% of this EFP is related to the indirect use of energy for fertilizer production mainly for nitrogen production.

Nitrogen fertilizers have the heist environment impact in the study areas where it is responsible about the potential of 77.73% global warming, 68.93%of smog, 63.30% of acidification, 60.94% of ecotoxicity, 53.94% of carcinogenic, 62.57% of non-carcinogenic, 44.17%, of respiratory effects, and 45.32% of fossil fuel depletion. Herbicides are responsible about the 27.98% of ozone depletion potential in the study area. In 2030, Environment impact of each influence category will be raised by about 26%. The ecosystem service capacity will be the most disfigurement due to the high increase in the eutrophication influence. The increase in eutrophication influence is resulting from the increase in P and N loads to the freshwater. Where, P load and N load will increase from 1.29 and 8.2 million ton in 2016 to 1.49 and 9.7 million ton in 2030.

The net farm return in WLEB will increase by about $ 78 million in 2030 more than its value in 2016. The contribution of the ethanol production to the economy will increase from $ 263 million in 2016 to $369 million in 2030. Mass and economic water productivity will increase from 5.64E-05 to 6.53E-05 ton /m^3 and from 1.44E-01 to 1.27E-01 \$/m^3 respectively. Mass and energy productivity will increase from 2.19E-04 to 2.64E-04 ton/MJ and from 1.83E-02 to 2.04E-02 $/MJ. The labour force will increase by about 19%. Due to the increasing in the corn exports from the study area, the virtual WFP and EFP through the crop trade will increase by about 101 BCM and 224 TJ respectively in 2030.

The research illustrated that analysis of water-food-energy with considering and modeling its linkage with the environment, economic, and social aspects in a holistic manner is significant. The approach of this research and its outputs can be utilized as a guideline scheme for the decision makers to integrate water-food-energy-ecosystem-environment nexus with economic and social aspects based on the life cycle assessment thinking. The developed WLF4ES matrix help in setting polices and strategies for managing the nexus in the basin.

5. Declarations

Authors Contributions: Inas El-Gafy (Corresponding Author): Conceptualization; methodology; review previous research ; create the system dynamic model; coding; data collection ; validation the system dynamic model; analysis and evaluation of results; writing; review & editing. Defne Apul (Author 2): Conceptualization; LCA data collection, analysis and evaluation of results; review & editing.

Data Availability: All data used during the study is illustrated in the submitted article.

Code Availability: Vensim model has been used for this study. All code made is illustrated in the submitted article.

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Conflict of Interest: The authors declare that they have no conflict of interest.

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Figures

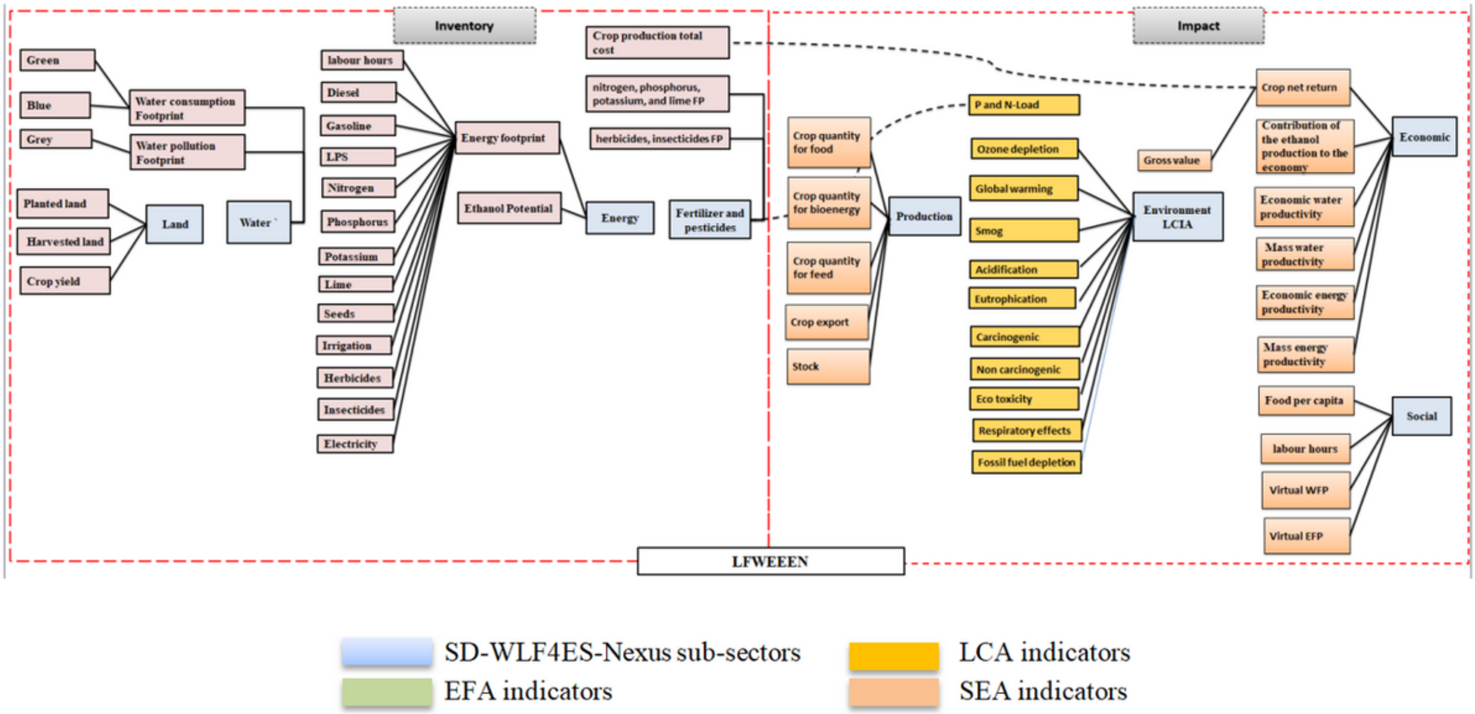

Figure 1

Proposed EFA, LAC, and SEA indicators for amalgamating WLF4ES nexus

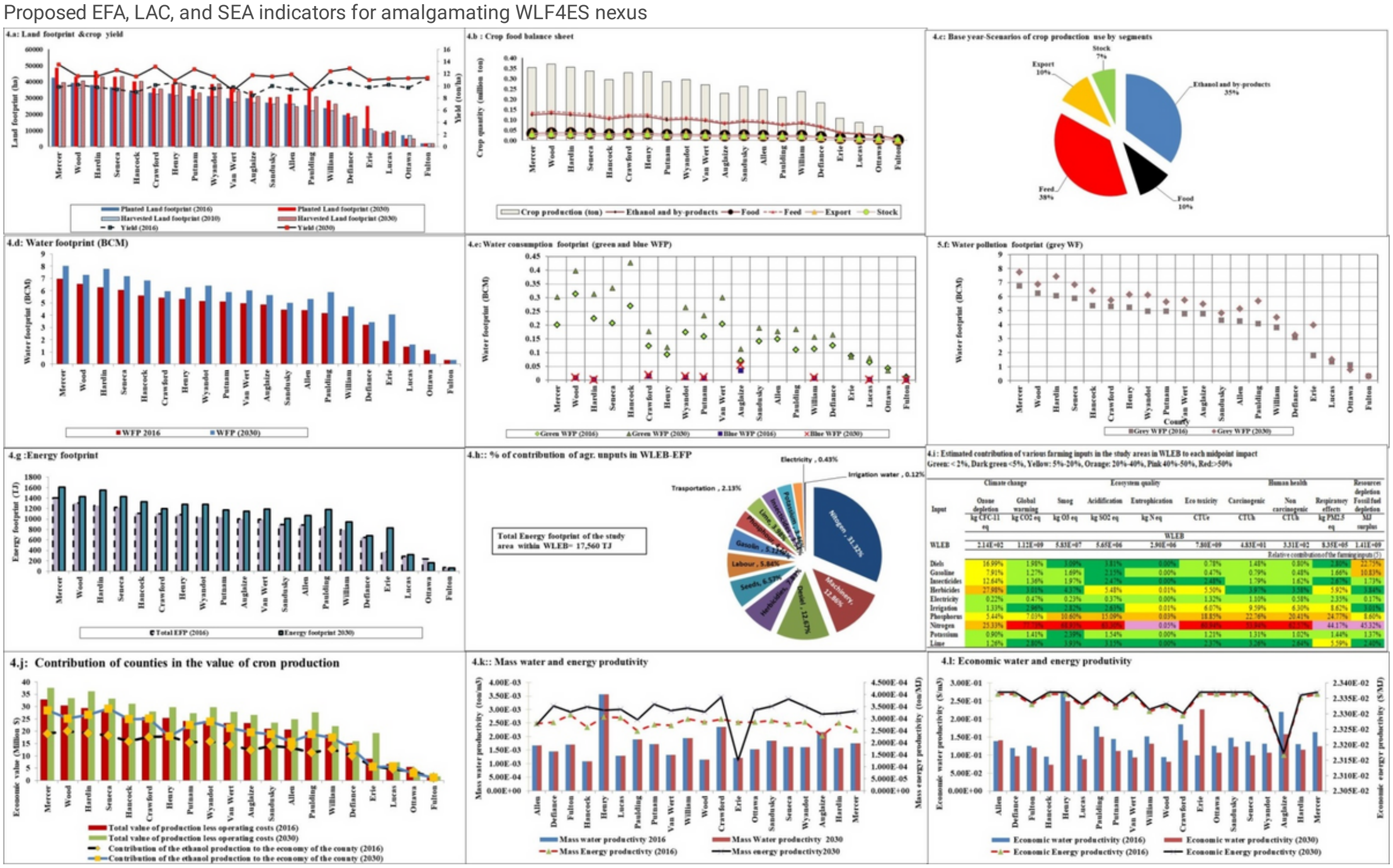

Figure 2

Corn's WLF4ES Nexus in WLEB' Counties (2016-2030)

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