Pollution Prevention Project: Life Cycle Assessment (LCA) of Lentil Texturized Vegetable Protein (TVP)

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Ravi Kumar Pirati

- I was born in Andhra Pradesh, India.

- **Professional Background:**

I worked for Pharmaceutical firms as Scale-Up Technology Transfer Engineer and Production planning and Inventory Control (PPIC) in SCM for 3 years.

- **Academic Background:**

- Bachelors in Chem Eng. from Vignan's University, India.

- Currently perusing masters in Chem Eng. from Montana State University.

- **Career Goal:**

Chemical engineer contributing services towards improving process safety in manufacturing sector.

What is TVP

- Texturized vegetable protein is a meat substitute product that's made from soybeans by extrusion of soy protein.

- Extrusion: Set of mixed ingredients forced through in a perforated plate or die with a design specific to food, involves mixing, cooking, kneading, shearing and shaping.

Extrusion of TVP

Calcium hydroxide
Sodium bisulphite
Xanthum gum
Protein

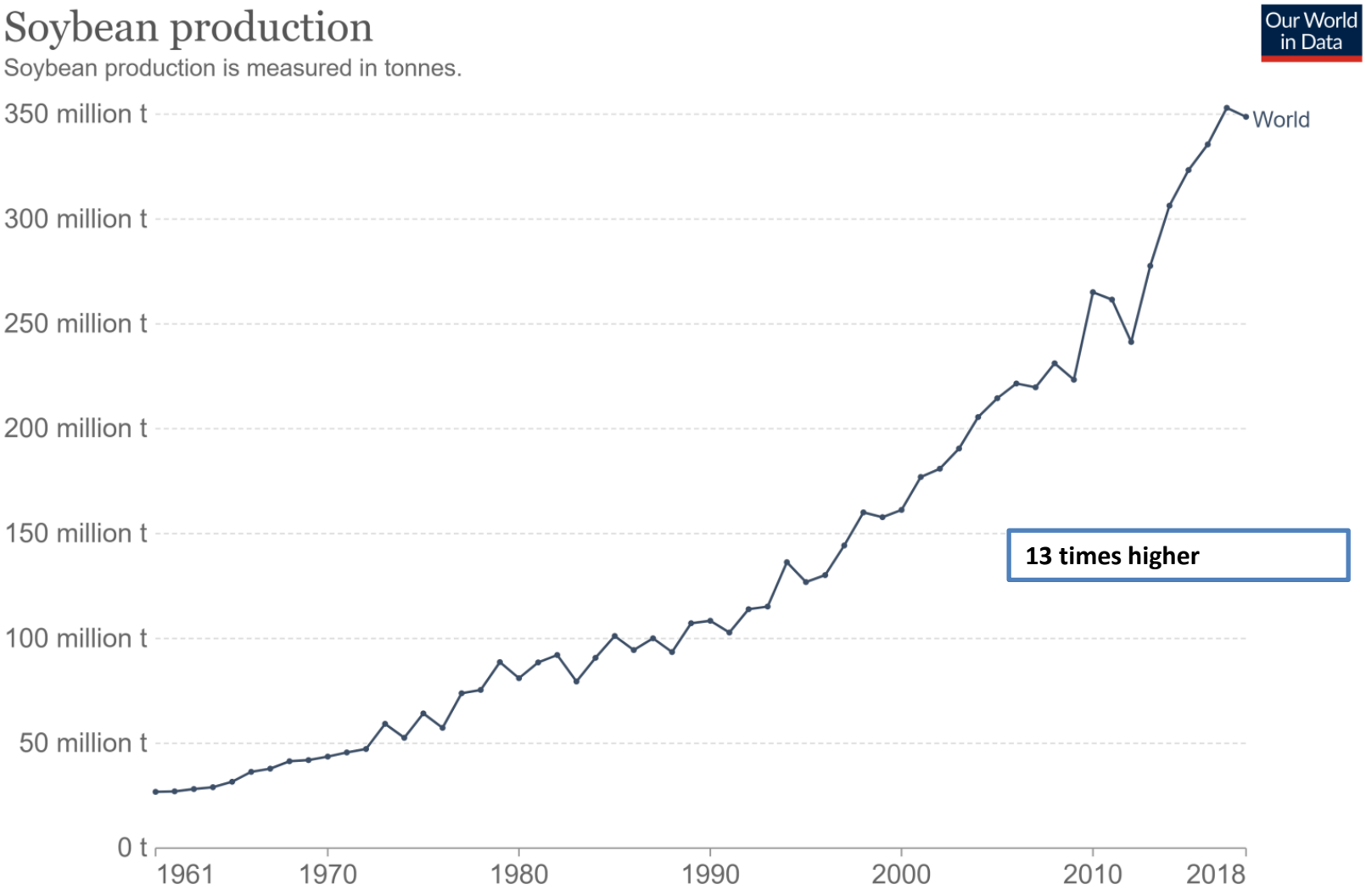
Soy

The king of Beans

- Globally traded commodity produced both temperature and tropical regions.
- Serves as key source of protein and vegetable oils.
- Over 80% of worlds soy from United states, Brazil and Argentina.

Soybean production

Soybean production is measured in tonnes.

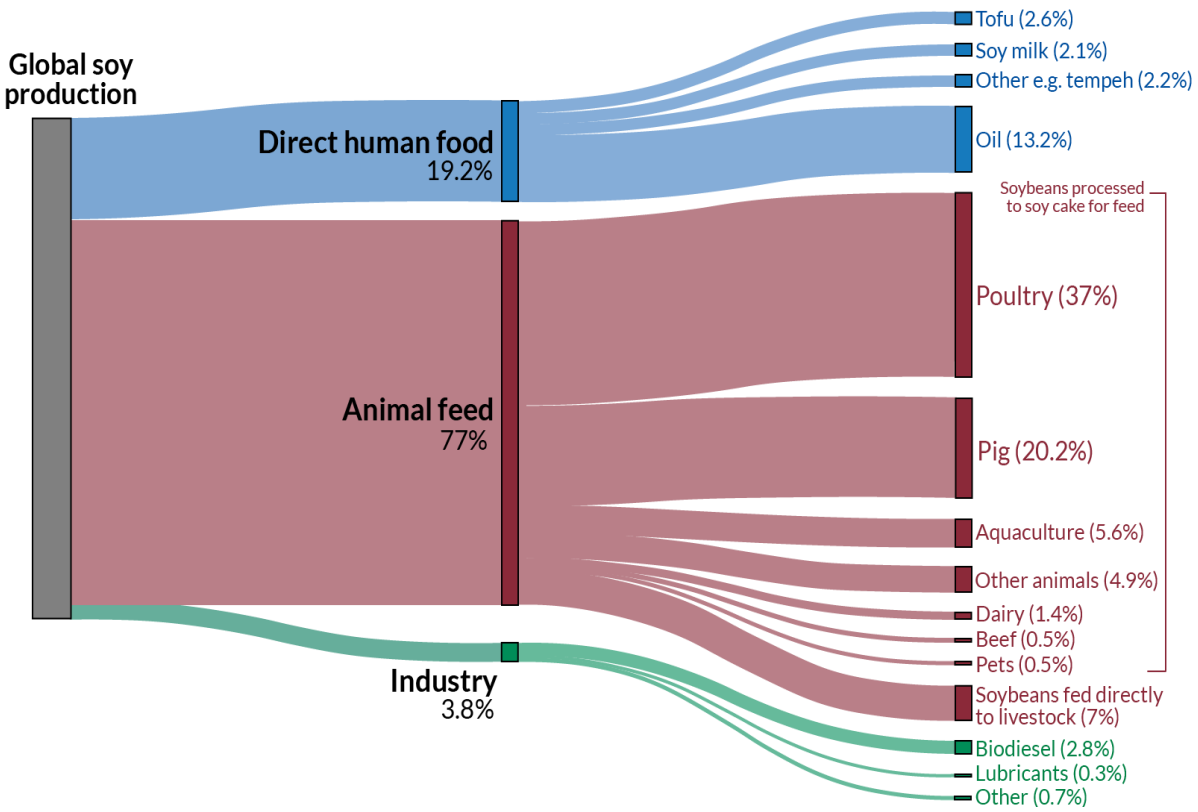


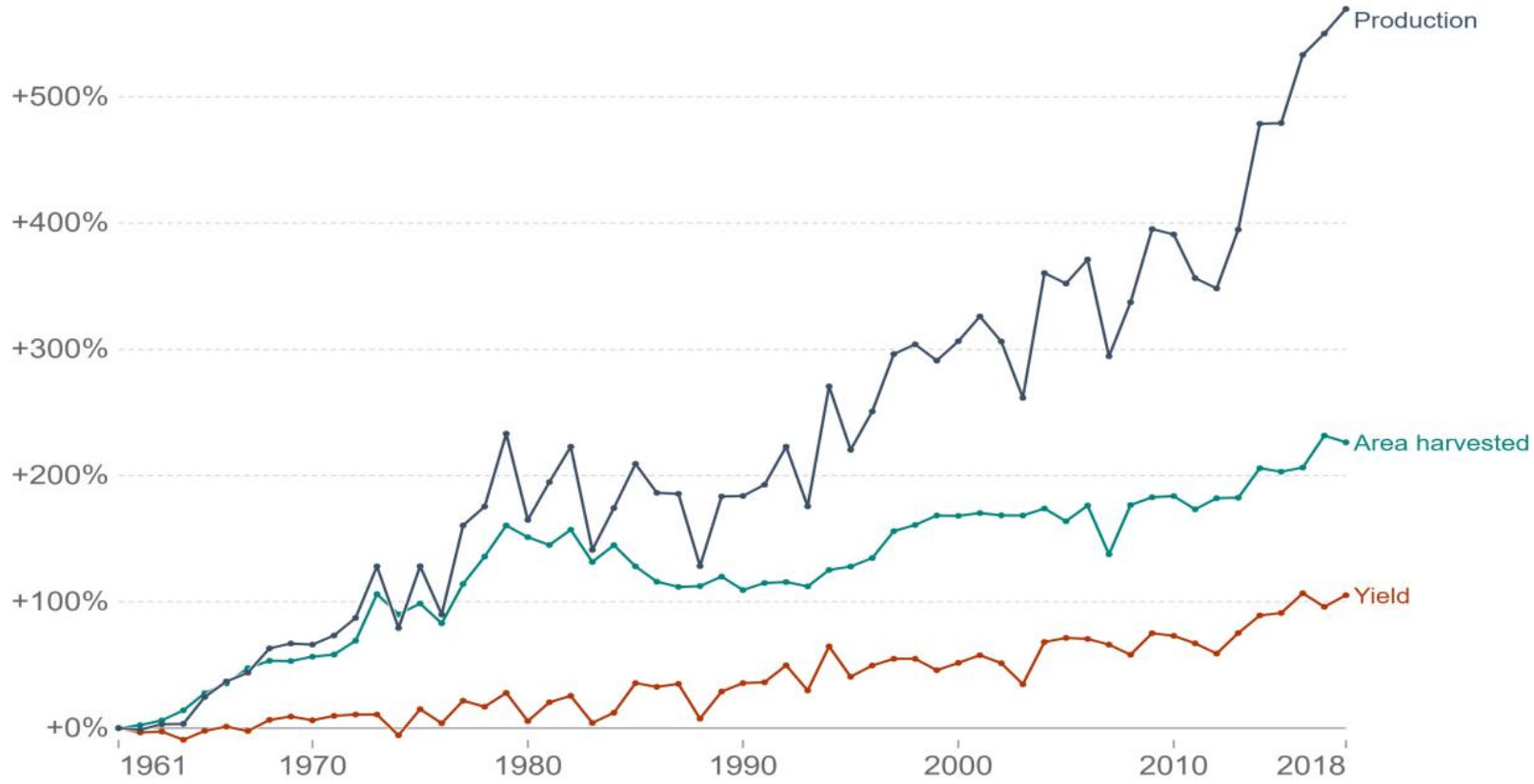
Source: UN Food and Agriculture Organization (FAO)

OurWorldInData.org/agricultural-production • CC BY

Soy consumption

- We can increase agricultural production in two ways:
  - by improving yields
  - Expanding the amount of land use




Production
Area harvested
Yield
+500%
+400%
+300%
+200%
+100%
+0%
1961
1970
1980
1990
2000
2010
2018

Is soy production driving deforestation?

- Since 1961, Global yields 150%
  Production 1200%

❖ Some studies concluded – it is pasture lands not soy bean farming driving deforestation in Brazilian Amazon.

❖ Crop lands replacing pasture and pasture lands shifting to forest areas and most deforestation is driven by expanding pastures or soy.

✓ **According to US dept of Agriculture, 94% of soy production consists of genetically modified beans.**

Lentils

Montana – Largest producer of lentils in United States, accounts 38% of lentils grown in nation.

Protein rich lentils are drought resistance, ideal crop to grow in Montana's dry climate.

As a legume, Lentils take nitrogen from atmosphere and convert it to a nutrient source in soil to feed crops grown after them.

Organic Lentils farming in Montana

- Land Preparation (Ploughing): Cultivator, shallow tillage tool and roller.
- Sowing: Air seeder, 60 lb seeds and 2 kg Rhizobium bacteria.
- No irrigation, depends only on rainfall and late winter snowfall (i.e., 9 – 16 inches).
- Cutting by Swather.
- Drying: 7-10 days.
- Harvesting: Combine harvester.
- Yield: 600 lb/acre (15-20% foreign materials like weed seeds & rocks per every 100 lb)

What is Life Cycle Assessment (LCA) ?

- Technique that allows identifying the overall environmental effects of the life cycle of a product or process, by evaluating the potential environmental impacts of a system through detailed study of the inputs of energy and mass in the production life cycle, including transportation.

Phases of Life Cycle Assessment (ISO 14040 & ISO 14044):

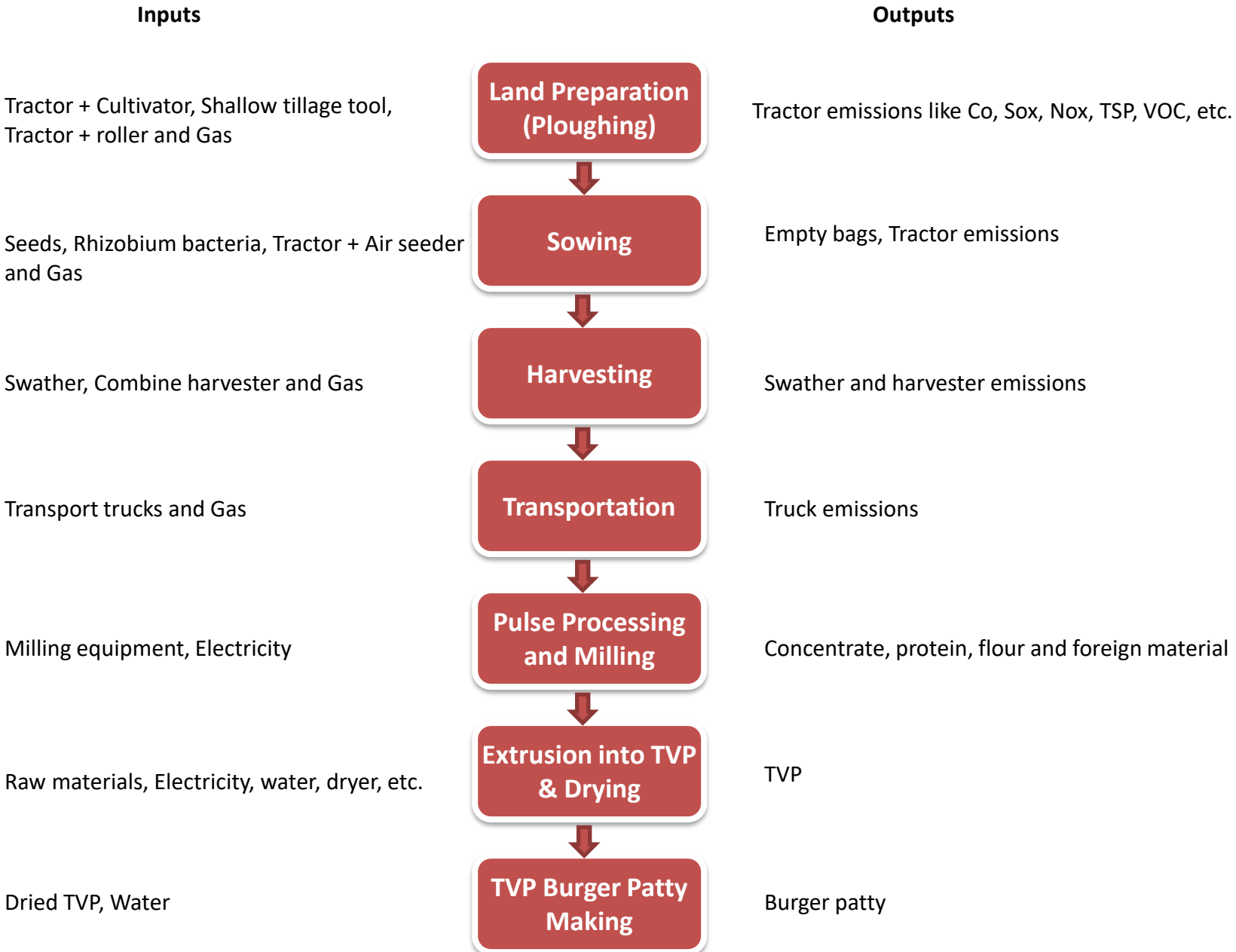
- ✓ Goal and scope definition: Determining boundaries for study.
- ✓ Inventory analysis : Data on inputs and outputs for all processes.
- ✓ Impact assessment : Contribution in impact categories such as water consumption, global warming etc.
- ✓ Interpretation : Major contributions, analysis, what can be learned from study?

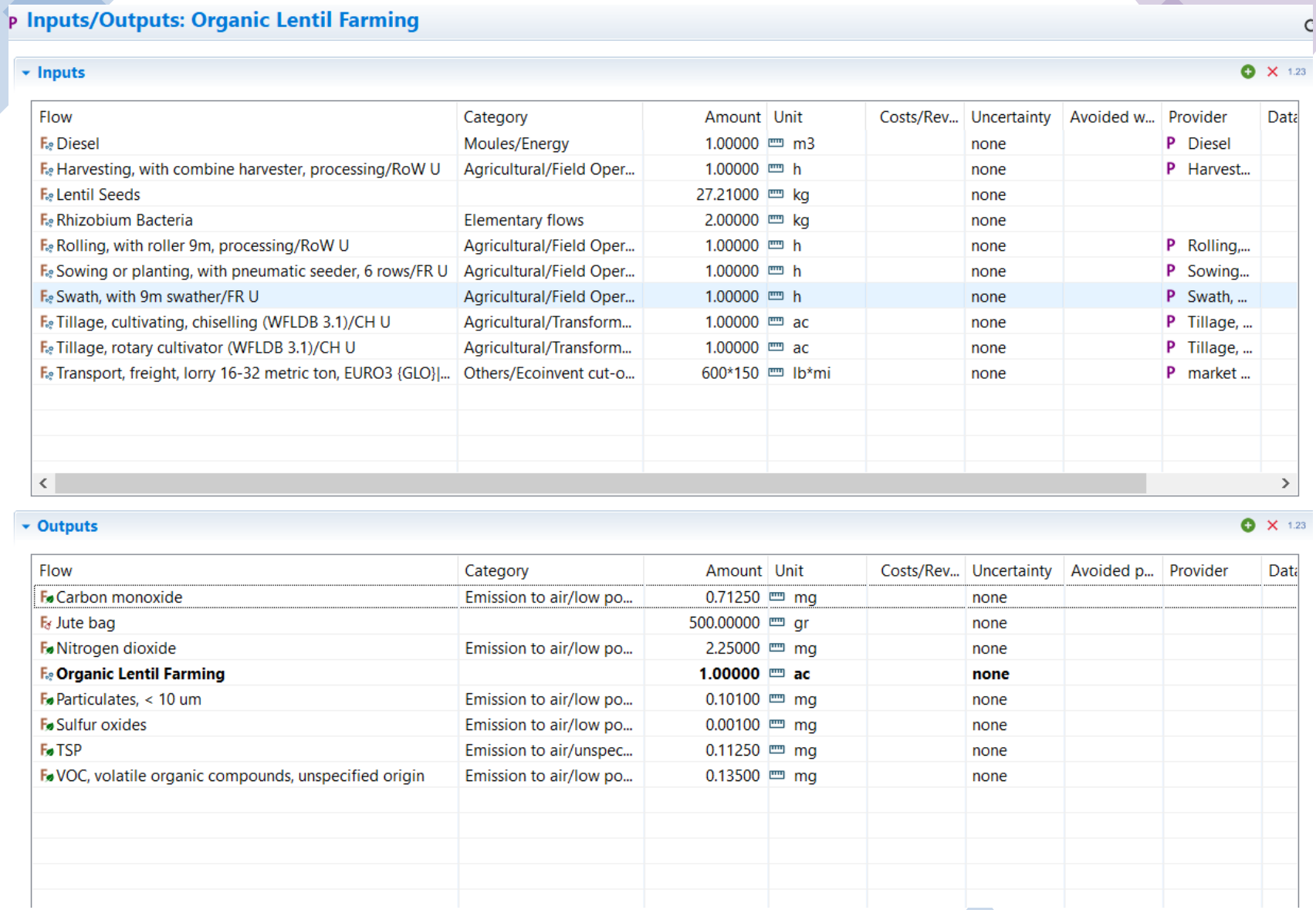
- **Goal and scope of study:** The primary goal of this study was to evaluate impacts associated with soy and lentil farming in United States.
- **Functional unit:** A functional unit of one acre land was selected for this study.
- **Cradle-to-farmgate:** includes ploughing, sowing of seeds and all other on-farm activities associated with cultivation of lentils.
- OpenLCA
- Database: AGRIBALYSE for agriculture and food sector.
- Impact assessment method: ReCiPe 2016 Midpoint(H).

Flow Diagram of Lentil TVP

Fig: Flow Diagram of Lentil TVP

System Boundaries of LCA





Inputs/Outputs: Organic Lentil Farming

Inputs

Flow	Category	Amount	Unit	Costs/Rev...	Uncertainty	Avoided w...	Provider	Data
Diesel	Moules/Energy	1.00000	m3		none		Diesel	
Harvesting, with combine harvester, processing/RoW U	Agricultural/Field Oper...	1.00000	h		none		Harvest...	
Lentil Seeds		27.21000	kg		none			
Rhizobium Bacteria	Elementary flows	2.00000	kg		none			
Rolling, with roller 9m, processing/RoW U	Agricultural/Field Oper...	1.00000	h		none		Rolling,...	
Sowing or planting, with pneumatic seeder, 6 rows/FR U	Agricultural/Field Oper...	1.00000	h		none		Sowing...	
Swath, with 9m swather/FR U	Agricultural/Field Oper...	1.00000	h		none		Swath, ...	
Tillage, cultivating, chiselling (WFLDB 3.1)/CH U	Agricultural/Transform...	1.00000	ac		none		Tillage, ...	
Tillage, rotary cultivator (WFLDB 3.1)/CH U	Agricultural/Transform...	1.00000	ac		none		Tillage, ...	
Transport, freight, lorry 16-32 metric ton, EURO3 {GLO}|...	Others/Ecoinvent cut-o...	600*150	lb*mi		none		market ...	

Outputs

Flow	Category	Amount	Unit	Costs/Rev...	Uncertainty	Avoided p...	Provider	Data
Carbon monoxide	Emission to air/low po...	0.71250	mg		none			
Jute bag		500.00000	gr		none			
Nitrogen dioxide	Emission to air/low po...	2.25000	mg		none			
Organic Lentil Farming		**1.00000**	**ac**		**none**			
Particulates, < 10 um	Emission to air/low po...	0.10100	mg		none			
Sulfur oxides	Emission to air/low po...	0.00100	mg		none			
TSP	Emission to air/unspec...	0.11250	mg		none			
VOC, volatile organic compounds, unspecified origin	Emission to air/low po...	0.13500	mg		none			

Fig: Inputs & outputs from OpenLCA

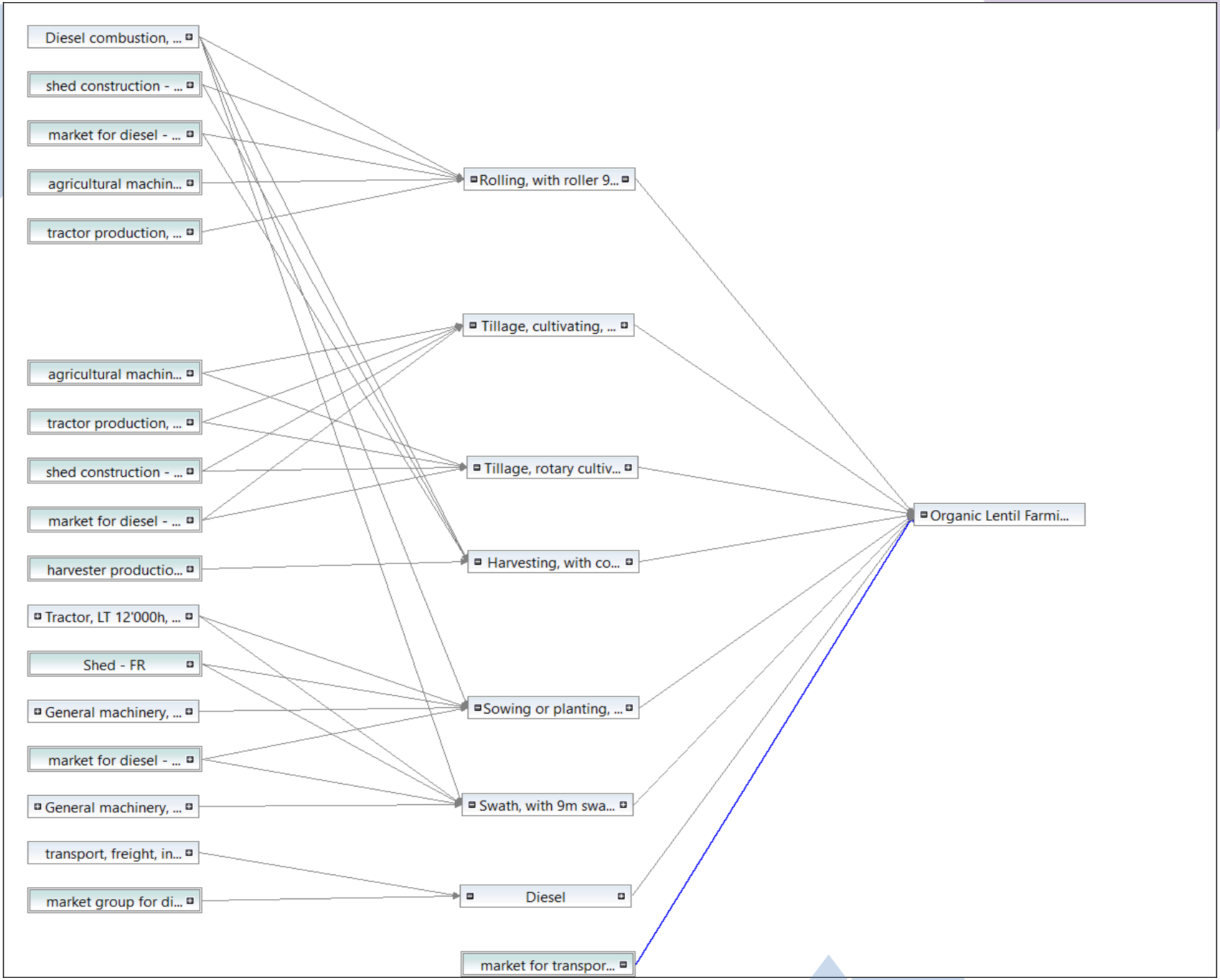


Fig: Model Graph

Impact Assessment for organic farming of lentils

- Global warming potential for conventional soy farming is **18963.04 kg co2 eq per acre**.

Name	Impact result	unit
Fine particulate matter formation	7.871836255	kg PM2.5 eq
Fossil resource scarcity	1159.046787	kg oil eq
Freshwater ecotoxicity	9.829355626	kg 1,4-DCB
Freshwater eutrophication	0.102276328	kg P eq
Global warming	**3561.247477**	**kg CO2 eq**
Human carcinogenic toxicity	19.67937621	kg 1,4-DCB
Human non-carcinogenic toxicity	699.2996429	kg 1,4-DCB
Ionizing radiation	51.32674072	kBq Co-60 eq
Land use	9.651881386	m2a crop eq
Marine ecotoxicity	16.87776291	kg 1,4-DCB
Marine eutrophication	0.020371859	kg N eq
Mineral resource scarcity	2.727417621	kg Cu eq
Ozone formation, Human health	47.76736149	kg NOx eq
Ozone formation, Terrestrial ecosystems	48.01830611	kg NOx eq
Stratospheric ozone depletion	0.004049648	kg CFC11 eq
Terrestrial acidification	21.56801495	kg SO2 eq
Terrestrial ecotoxicity	4544.492452	kg 1,4-DCB
Water consumption	6.104927531	m3

Comparison on conventional farming

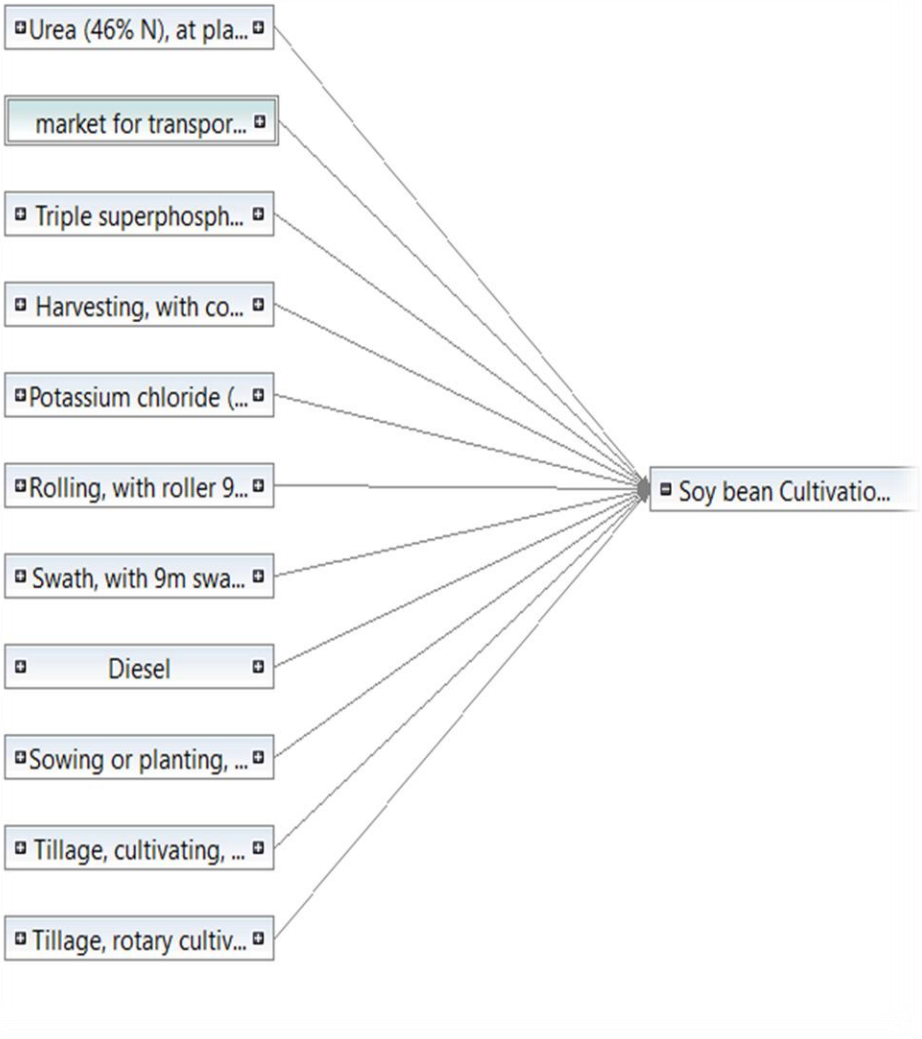


Fig: Model Graph for soy cultivation

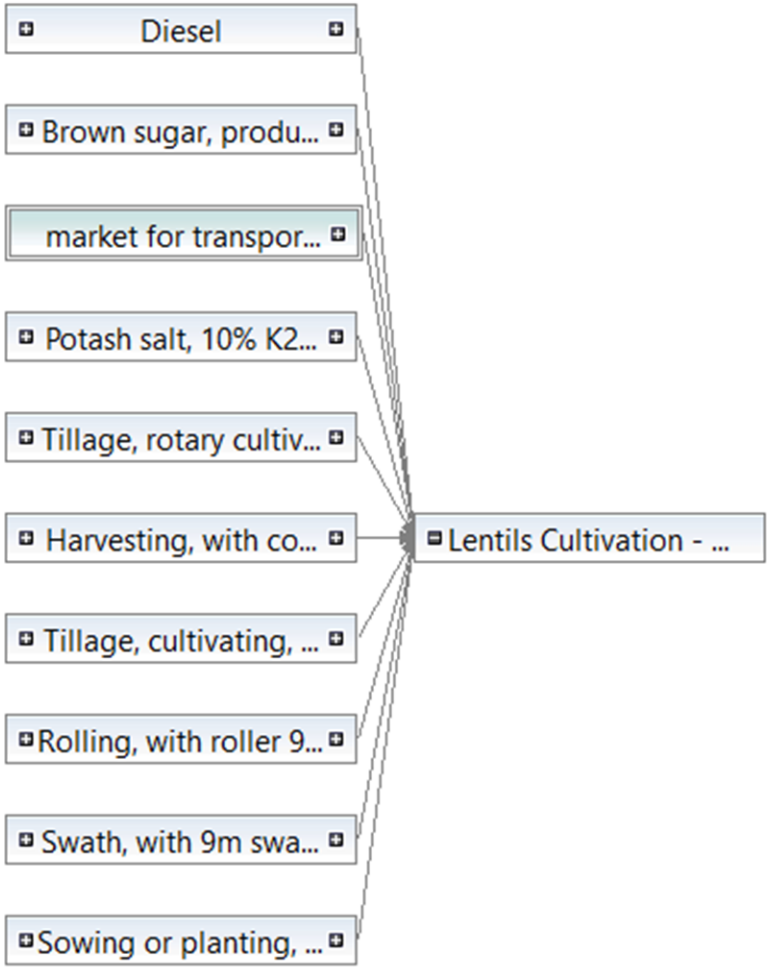
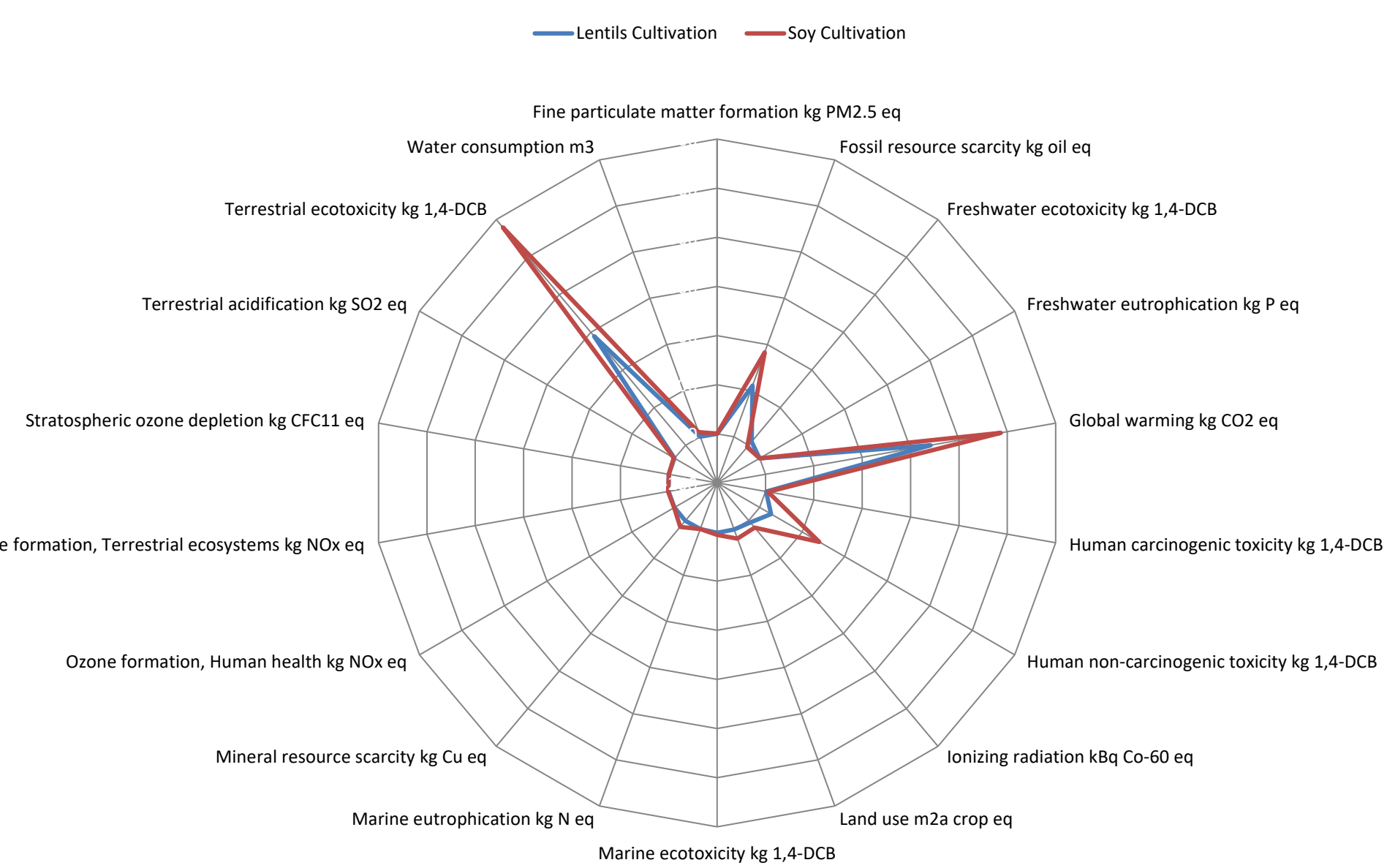


Fig: Model Graph for lentil cultivation

Impact Assessment comparison for conventional farming

Impact category	unit	Lentils Cultivation	Soy Cultivation
Fine particulate matter formation	kg PM2.5 eq	32.54406566	33.63063684
Fossil resource scarcity	kg oil eq	6405.965333	6550.07081
Freshwater ecotoxicity	kg 1,4-DCB	261.5950961	233.5825171
Freshwater eutrophication	kg P eq	1.429531364	1.623100744
Global warming	**kg CO2 eq**	**18672.59594**	**18963.04164**
Human carcinogenic toxicity	kg 1,4-DCB	352.5234035	360.1535488
Human non-carcinogenic toxicity	kg 1,4-DCB	12291.19001	12517.72659
Ionizing radiation	kBq Co-60 eq	346.1084308	374.261847
Land use	m2a crop eq	627.3780482	667.2161736
Marine ecotoxicity	kg 1,4-DCB	477.1770963	485.4236559
Marine eutrophication	kg N eq	0.157845602	0.179099851
Mineral resource scarcity	kg Cu eq	32.87258852	65.22562635
Ozone formation, Human health	kg NOx eq	151.0887388	153.7786308
Ozone formation, Terrestrial ecosystems	kg NOx eq	152.9648116	155.6699619
Stratospheric ozone depletion	kg CFC11 eq	0.00910054	0.009215811
Terrestrial acidification	kg SO2 eq	79.92158581	83.47772932
Terrestrial ecotoxicity	kg 1,4-DCB	264142.5242	264721.17
Water consumption	m3	47.54749501	66.80818148

Impact Assessment comparison for conventional farming



Conclusion

- Indicates Organic Lentils farming is more sustainable and less impact on environment.
- Soy farming driving towards pollution and deforestation in Amazon.
- Replacing of soy protein concentrate in TVP with lentil protein concentrate is feasible.

S.No	Farming Type	Global Warming Potential (GWP) (kg co2 eq per acre)	Stratospheric ozone depletion (kg CFC11 eq)
1	Organic Lentils	3561.24	0.0040
2	Conventional Lentils	18672.59	0.0091
3	Conventional Soy	18963.04	0.0092

Next steps

More Extrusion runs of TVP with all required raw materials and calculate energy requirements.

Make TVP burger patties with extruded lentil TVP.

Perform LCA on Cradle to Grave basis i.e., includes lentils farming, milling, transportation, extrusion and patty making.

Acknowledgements

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- Jennifer Grossenbacher and Watson Barbara, MTP2

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- https://www.agrifarming.in/soybean-farming-information
- https://albertapulse.com/lentil-seeding/lentil-fertility/

Thank you