A Comparison of Greenhouse Gas Emissions from Inputs into Farm Enterprises in Southeast Queensland, Australia

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ABSTRACT

One of the assumptions underlying efforts to convert cropping land, especially marginal crop land, to plantations is that there will be a net reduction in greenhouse gas emissions, with a gas 'sink' replacing a high energy system in which the breakdown of biomass is routinely accelerated to prepare for new crops. This research, based on case studies in Kingaroy in south-east Queensland, compares the amount of greenhouse gas (GHGs) emissions from a peanut/maize crop rotation, a pasture system for beef production and a spotted gum *(Corymbia citriodora)* timber plantation. Three production inputs, fuel, farm machinery and agrochemicals (fertilizer, pesticides and herbicides) are considered. The study extends beyond the farm gate to include packing and transportation and the time period is 30 years. The results suggest that replacing the crops with plantations would indeed reduce emissions but that a pasture system

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would have even lower net emissions. These findings cast some doubt on the case for farm forestry as a relatively effective means of ameliorating greenhouse gas emissions.

Key Words: greenhouse gas, farm machines, agrochemicals, fuels, Kingaroy

INTRODUCTION

Intensification in agriculture not only contributes to increased productivity but can reduce the pressure to clear native vegetation. For example, it has been estimated that increasing fertilizer use in developing countries (except China) has a net benefit of between 80 and 206 Mt yr^{-1} in carbon by saving the forest being cleared. [1] On the other hand, in developed countries where resource protection is as much, if not of more, concern than food and fibre production, there is an argument that some land should be less intensively used than is currently the case. Due to environmental concerns, the Queensland State Government has encouraged farmers to plant hardwood plantations on degraded cultivation and pasture areas [2, 3] and has approved a $30 million investment plan to increase the plantation area in Southeast Queensland. [4] This initiative is not solely or even primarily a carbon sequestration strategy but flows from earlier concerns at the national political level about logging in native forests [5] and the consequent conclusion of the need for an expansion of the plantation area as a substitute in supply. [6]

The target for the national strategy (Vision 2020) was for an expansion of the 1997 plantation area of 1.1 million ha to 3.33 million by 2020. [7] While it was recognised that small-scale farm plantations, would only be a small part of that total expansion, it was considered that in light of the other social benefits, including carbon sequestration, such plantations should be encouraged..[7] Since then, there have been several reports proposing that carbon payments for sequestration could be used to make farm plantations more financially attractive, [8, 9] an important consideration given that timber values alone are unlikely to yield a positive return in medium to low rainfall areas (600-800 mm/year). [10] Setting aside the issues in creating a functional carbon market, this research investigates the relative carbon budgets that would be generated by two current conventional enterprises and a proposed new land use activity, plantations in the South Burnett region of Queensland.

This study considers the inputs into each of a peanut/maize crop rotation; beef production based on exotic pasture; and spotted gum *(Corymbia citriodora)* grown mainly for construction timber. All direct production activities are included, as well as the production, packaging and transport of the agrochemicals (fertilizer, herbicides, insecticides and fungicides), fuel and machinery used in production of each of the commodities. While there has been extensive work on carbon budgets for on-farm activities (see for example Carbon Farmer) there has to date only been limited work on extending that budgeting to include the off-farm inputs to production. [11] For example, of the total energy used in world agriculture, about 51% has been used for farm machinery manufacture and 45% for the production of chemical fertilizer. [12] Approximately 83.7 MJ is required to produce a kilo of farm machine. [13] There are some comparative researches on soil C, [14, 15] biomass C, harvested product's C and methane in three competitive land use systems (peanut-maize, pasture and plantation) in Kingaroy but no research on emissions from primary farm inputs. [14]

This study was conducted by taking case examples of three land uses; grazed pasture and plantations from one farm and a peanut (*Arachis hypogaea*)-maize (*Zea mays*) rotation at the neighbouring farm. This rotation is necessary for crop husbandry reasons. These sites are located near Kingaroy (26° 35'S, 151° 50'E) in Southeast Queensland, approximately 215 km

North West of Brisbane. The climate is classified as subtropical, with long summers, with an average maximum temperature of 24.7°C, and mild winters with an average minimum of 11.4°C. The annual rainfall ranges from 339 to 1430 mm, with an average of 781 mm, and is summer-dominant with about 70% falling between October and March. Frosts also occur during winter.

METHODS

For all major production processes creating the inputs for forestry and agriculture, greenhouse gas emissions released directly, or as a result of energy use were calculated. The estimation of emissions from energy use is based on coal as the source of energy. About 0.41 kg CO_2 is emitted for each kilo watt hour (KWhr) of electricity production from coal. [16] While producing electricity from coal other greenhouse gases (methane and nitrous oxides) produce as well. The amount of methane and nitrous oxides were calculated on the basis of total amount of these gases and electricity produced in Australia from black coal, a major type of coal in Australia. [17] The calculation shows that around 0.411 kg carbon dioxide equivalents (CO_2e) GHGs is emitted into the atmosphere while producing one KWhr of energy (Table-1).

Farm Machinery

On average approximately 83.7 MJ of energy is required to produce a kilo of farm machine (Stout, 1990). Since 1 KWhr = 3.6 MJ, 23.25 (83.7/3.6) KWhrs are required for each of those machinery kilos. Hence, the CO_2e GHGs emitted into the atmosphere while producing each kg of machinery must be 9.6 kg (0.411 x 23.25). Some GHGs would be emitted while transporting the machines but it is negligible on a per ha basis and is not considered in this study.

Data for peanut and maize cropping machinery operations were taken from state agriculture agency notes [18] and other sources [19-21] and verified by the relevant landholders and state extension officers. Data for machines used to establish pasture were taken from a landholder while that for plantations came from the local state agency plantations extension officer. The life span of machineries and accessory equipments were taken from Harris [21] and the weight of machines and accessories were taken from production companies. [22, 23] The fraction of time a particular machine used for a particular operation was derived from crop production publications noted earlier and independently verified by landholders and extension officers. From that information, the following equation was developed to estimate the GHGs emissions for using particular machinery to particular land use.

GHGs emission (kgCO_2e/ha) = Weight of machine (kg) x 9.6 kgCO_2e kg^{-1} x Fraction of lifespan of that machine used for a ha of that land use……………………………….1

Production, Packing, Transportation and Application of Agrochemicals

In later stage cropping areas, input requirements increase, especially fertilizer and plant protection chemicals. The Red Ferrosol soils at the study sites have been farmed for at least 50 years and so nitrogen (N) fertilizer boosts crops and some pastures. Relative to other fertilizers such as phosphorus and potassium, nitrogen requires more energy for its production. [1, 12] Furthermore, crops such as peanuts require considerable crop protection from disease and pests and more energy is required in the production of insecticides, herbicides and fungicides on a per unit basis than any other input into agriculture. [12, 24] Hence, an increase in agrochemical inputs is likely to mean in an increase in emissions at some point in the production chain.

There are two common procedures for estimating GHGs emission from agrochemical inputs: estimating the amount of energy for the all process of production, packing, transportation and application; and then estimating GHGs emissions from that energy (3.6 MJ=1 kwh=0.411kgCO_2e GHGs); or estimating the global warming potential of each agrochemical. The Government of the State of Sao Paulo [24] has estimated the amount of energy required for producing different agrochemicals in Brazil. Mudahar and Hignett [25] estimated the energy requirement for production, packing, transportation and applications of fertilizers. Shapouri *et al.* [26] estimated the energy required for the production of fertilizers and pesticides in USA. Kim and Dale [27] independently estimated the amount of energy required for the production, packing, transportation and application of fertilizers.

However, the estimation of net GHGs emissions from these studies seemed quite difficult. Because many chemical reactions are exothermic, they release energy during the reaction. Since there is no information about how much energy was released during reaction, it is hard to find actual amount of external energy needed during their production. Although the total energy figure gives some clue about the relative emissions of different agrochemicals, it was not appropriate to use as such. Therefore, the second option, global warming potential, of all agrochemicals was preferred for this study.

Kim and Dale [27] estimated the global warming impact value (gm CO_2 equivalent kg^{-1}) of most of the agrochemicals (Table 2). The global warming impact value (GWIV) included all three GHGs (CO_2, CH_4 and N_2O) and their impact due to their production, packing, transportation and application. Not only this, GWIV also considered the emission of N_2O during the process of denitrification after applying nitrogen fertilisers. [27] As it covers broad impact, we used these values for the estimation of GHGs emission by the agrochemicals. The GWIV for insecticides and fungicides is not available in their estimation. For them, we used the value of pesticides as it covers both insecticides and fungicides. In case of mixed fertiliser, the value of main fertiliser was used, if there was only one element among the N, P and K, and if there were two main elements average of two was taken.

Production, Transportation and Combustion of Fuel

There are a number of studies of the production, transportation and combustion of petroleum products. In the Australian context, Beer *et al.*, [28] AGO [29] and Nussey [30] independently estimated the total carbon emissions during the production and combustion of fossil fuel. According to Bear *et al.* [28] each litre of diesel produces 0.45 kg and 2.59 kg of CO_2 during production and combustion, respectively. The respective values estimated by AGO are 0.46 and 2.69 kg. Combustion of fossil fuel also emits methane and nitrous oxide. Nussey [30] estimated that each litre of diesel combustion gives of 2.66 kg CO_2, 0.000383 kg methane (0.00802kg CO_2e) and 0.0007645 kg nitrous oxide (0.237kg CO_2e). Since all studies are quite reliable the average value {(0.45+0.46)/2=0.455} of two studies [28, 29] was used for the estimation of greenhouse gas emissions during the production of diesel and average of all three studies was taken for the estimation of CO_2 emissions during combustions of diesel {(2.59+2.69+2.66)/3=2.65kg L^{-1}). Therefore, the total greenhouse gases emissions during the productions and combustion of one litre of diesel is 3.35kgCO_2 L^{-1} (0.455+2.65+0.00802+0.237=3.35kgCO_2 L^{-1}).

Some amount of GHGs emissions also occurred during the transportation of fuels, but this would be negligible if we consider transportation from Petrol Station at Kingaroy to the farm.

For example, if we use 160KW tanker for 1 hour (round trip) with 17,000 L capacity the total fuel consumption per litre for transportation would be around 0.0023 Lt (160*0.25/17000), which would produce around 0.008 kgCO_2e. Therefore, for the purpose of this study GHGs emission due to transportation of fuel is not considered.

The amount of fuel consumed in the establishment, production, harvesting and transportation of all land use products of different land use types was derived form Harries [21] and was then independently verified and qualified where necessary by landholders and officers. The total amount of fuel consumption and GHGs emission from each litre of fuel was used to find the total amount of GHGs emission due to use of fuel.

RESULTS AND DISCUSSION

This Section is subdivided into three Subsections for the comparison of the amount of GHGs emissions from agrochemicals, fuel and farm machinery separately.

Emissions from Production, Packing, Transportation and Application of Agrochemicals

Agrochemicals cover all fertilizers, insecticides, fungicides and herbicides. The total amount of GHGs emission from agrochemicals used in the peanut and maize rotation is approximately 1139 kgCO_2e per year (Table 3 for summary and Table 4 in Annex for detail). Over 30 years, the total amount of GHGs emissions from cultivation (peanut-maize cropping) is around 17094 kgCO_2e. The total amount of GHGs emissions in pasture and plantation in 30 years is around 440 and 921 kgCO_2e respectively. The total amount of GHGs emission from cultivation in 30 years is around 39 times higher than pasture and 19 times higher than plantations.

There are four main reasons why cultivation has the highest amount of GHG emissions from agrochemicals. As noted earlier, nitrogen emits higher amount of GHGs than any other fertilizers and there is a higher requirement of that form of fertilizer. Although peanut fix a considerable amount of nitrogen the net nitrogen benefit to the next crop is minimal. [31-33].Therefore, every maize crop requires a significant amount of nitrogen fertilizer. On the other hand, in plantation and pasture, it is used only once in 30 years. There may be an argument for using some nitrogen at each stage of pasture re-establishment (every 8-10 years) but it is presumed that the pasture mix contains some legumes.

Second, a large amount of lime is used with the crops. Peanuts accelerate the soil acidity by removing cations, particularly Ca, Mg and K. [32] Moreover, calcium is absorbed directly by developing pods and low calcium leads to empty shells. [34] In order to neutralise the acidity problem 820 kg per ha of lime is used every year, whereas there is no need of lime in the pasture and plantation. Third, the higher amount of other fertilizers need in cultivation is directly related with higher frequency of peanut cropping (every second year), conventional tillage and removal of hay for its higher price. [35] While removing every ton of peanut hay, around 40 kg of muriate of potash and 16 kg of superphosphate equivalent would be removed. [34] Similarly, nuts in shell will remove around 16 kg of muriate of potash and 30 kg of super in each ton. [34] Fourth, since more GHGs is emitted into the atmosphere in the production of insecticides, herbicides and fungicides on a per unit basis than any other input in the agriculture, [12, 24] a rotation such as this with susceptible crops, widely grown in the region increases the chances of disease and pest problems, leading to a commensurate increase in emissions.

Emissions from the Use of Farm Machinery

As with the agrochemicals, the use of machinery in crop production results in the highest amount of consequent GHGs emission (1910 $kgCO_2e$ ha^{-1}) in 30 years, around 15.65 times higher than for the pasture and 1.27 times higher than for the plantation (Table 3 for summary and Table 5 in Annex for detail). In pasture the emission of GHGs due to farm machinery production and use is almost nil, just 122 $kgCO_2e$ in 30 years due to the infrequent need for cultivation and planting. On the other hand, there is much less difference between the plantation and the cropping (1500 vs 1910 $kgCO_2e$ per ha in 30 year). Although a range of machines are used in cropping every year, the duration of each operation is relatively short. In plantation, machines were not used every year but they were used heavily during the first, fourth (commercial thinning) and thirtieth (final harvesting) years. Notably, a significant amount of GHGs emission from plantation work comes from harvesting operations which include skidding, loading, transportation and unloading. Since the processing centre for timber is farther from the site (35km) than the collection point for peanuts, maize and beef (Kingaroy, around 15 km), machine use time for selling harvested goods in plantation is higher than the others.

Fuel Emissions

Since the emissions of GHGs during the application of agrochemicals have already been considered in agrochemical section, the fuel consumption (and GHGs emission) during the application of agrochemical is not included in these data. As could be anticipated from the operation of machinery, the emissions of GHGs in 30 years due to use of fuel in the cropping system is highest (13272 $kgCO_2e$), followed by the plantation (7856 $kgCO_2e$) and pasture (996 $kgCO_2e$) (Table 3 for summary and Table 5 in Annex for detail). The emission of GHGs due to consumption of fuel in cropping is almost 13.3 times higher than in pasture and 1.7 times higher than in plantation. The higher the power requirement for a particular operation the higher the fuel consumption and high power machines are used for deep ripping and digging operations in peanuts, and ripping and hilling operations in plantations. In addition, there is once again the effect of frequent machinery use with the cropping.

CONCLUSIONS

This study has demonstrated that there is a significant difference in GHG emissions due to the application of three primary farm inputs (agrochemicals, machinery and fuels) in cropping, pasture and plantation lands over 30 years. In total, approximately 32.3, 1.6 and 10.3 ton of CO_2e per ha GHG will be emitted into the atmosphere from the crop, pasture and plantation enterprises respectively. This indicates that planting trees on ex-cultivated land has considerable GHGs benefit but there would be a negative effect if trees were planted on current pastureland. The net difference of around 22tCO_2e per ha of GHGs between plantation and cropping only from primary farm inputs has implications for achieving 'Vision 2020'. Some caution is needed in extrapolating from these findings, given that this is a particular cropping system with relatively intensive on-ground activities. A reduced tillage system, for example, may result in a more favourable outcome for cropping, depending on the agrochemical inputs needed. Nonetheless, long-rotation pasture would still be likely to be the low emission option.

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Table 1. Emissions of major GHGs for the production of one KWhr electricity

Activity	CO_2	CH_4	N_2O	CO_2e
Emissions of GHGs (Giga gram) while producing 1193 PJ of electricity[1]	-	1.05	0.98	
Emissions (gram) while producing 1KWh of electricity	410[a]	0.0032	0.003	
Carbon dioxide equivalent (CO_2e) while producing 1KWh of electricity	410	0.067	0.93	0.411kg

[1] AGO [17], [a] URS [16]

Note: One Kilo watt hour (KWhr) = 3,600 KJ, global warming impact of 1 kg of N_2O=310 kg CO_2 and 1 kg of CH_4=21 kg CO_2.

Table 2. Global warming impact (GWI) (gm CO_2 equivalent kg^{-1}) of agrochemicals

Chemicals	GWI[1]	Chemicals	GWI	Chemicals	GWI
Nitrogen	3270	Herbicides	22800	Lime	42.1
Phosphorus	1340	Pesticides	24500		
Potassium	642	Boron	335		

Source: Kim and Dale [27]

Table 3. Emissions of greenhouse gases (kgCO_2e ha^{-1}) from primary farm inputs in different land use systems in Kingaroy in 30 years, Southeast Queensland

Emissions due to	Emissions of greenhouse gases (kgCO_2e/ha) in different land uses		
	Peanut-maize cropping	Pasture	Plantation
Agrochemicals	17094	439.5	921.42
Machinery	1910.03	122.08	1500.1
Fuel	13272	995.57	7856.07
Total	32276.03	1557.15	10278

Annexes

Table 4. GHGs emission (kgCO2e ha^{-1}) from agrochemicals in different land use systems

Chemical	CO_2e per kg	GHGs emission (kgCO_2e ha^{-1}) in different land use systems							
		Peanut (per yr)		Maize (per yr)		Pasture (30 yrs)		Plantation (30 yrs)	
		Kg Per ha	total CO_2e	kg/ha	total CO_2e	kg/ha	total CO_2e	kg/ha	total CO_2e
N	3.27	0	0	110	359.7	110	359.7	226	739.02
P	1.34	0	0	0	0	0	0	0	0
K	0.642	0	0	0	0	0	0	0	0
Lime	0.042	820	34.44	820	34.44	0	0	0	0
Insecticide	24.5	2	49	0	0	0	0	0	0
Herbicide	22.8	7.05	160.7	6.9	157.32	3.5	79.8	8	182.4
Fungicide	24.5	2.6	63.7	0	0	0	0	0	0
Boron	0.335	2	0.67	0	0	0	0	0	0
CK1, main P	1.34	140	187.6	0	0	0	0	0	0
Starter Z, main P & N	2.30	0	0	40	92	0	0	0	0
			496.15		643.5		439.5		921.42
So in 30 yrs	Peanut & maize {(496.1+643.5)*15}				17094	Pasture	439.5	Plantation	921.42

Note: in case of mixed fertiliser CK1, P-value was taken and in Starter Z average of N and P was taken

Table 5. Estimation of GHGs emissions due to use of farm machinery and fuel in different land use systems in Kingaroy

Activity in different land use systems	Vehicle	Wt (kg)	Working life (WL) Hour	Worked hour per ha	wt of accessory	WL of accessory hour	Fuel L ha^{-1}	Emission of CO_2e Machine (kg/ha)	Emission of CO_2e Fuel (kg ha^{-1})
Peanut									
Deep ripping	168KW (8330)	10771	12500	0.59	1180	2000	24.70	8.20	82.75
Discing 2 times)	92KW (8330)	6277	12500	0.93	2504	2000	21.46	15.71	71.89
Cultivating	92KW (8330)	6277	12500	0.41	1524	2000	9.51	5.02	31.86
Planting/seeding	92KW (7520)	6277	12500	0.41	1219	2000	9.51	4.41	31.86
Self propelled sprayer (7 times)	75KW (6403)	3880	12500	0.55	571	2000	-	3.14	-
Digging	168KW (8330)	10771	12500	1.41	1000	2000	59.10	18.39	197.99
Fluffing/shaking	92KW (7520)	6277	12500	0.61		2000	14.05	2.94	47.07
Threshing (AMADAS9900)	193KW[a]	14300	12500	0.35	1200	2000	16.07	5.86	53.83
Baling & transportation	92KW (7520)	6277	12500	0.70	1500	2000	16.07	8.40	53.83
Pre-cleaning (10 t/hr)	75KW (6403)	3880	12500	0.20	2500	2000	3.75	3.00	12.56
Drying (capacity 15t@) 0.5% MC/hr), MC of 2 ton peanut decrease from 18 to 12%	30KW (990)	1340	8000	1.60	250	2000	12.00	4.49	40.20
Freight (2t, capacity @17ton@30min)	160KW (1710D)	8800	12500	0.03	6000	2000	1.18	1.05	3.95
Total emission of CO_2e (kg ha^{-1}) from peanut cropping in every cropping year								80.62	627.79
Maize									
Primary tillage	92KW (8330)	10771	12500	0.47	2504	2000	10.73	9.47	35.95
Inter-row tillage	92KW (8330)	10771	12500	0.41	2504	2000	9.54	8.42	31.96
Self propelled sprayer (8)	75KW (6403)	3880	12500	0.63	571	2000	-	3.59	-
Planting	92KW (7520)	6277	12500	0.41	1219	2000	9.51	4.41	31.86
Slashing	75KW (6403)	3880	12500	0.10	900	2000	2.00	0.73	6.70
Maize harvester(AMADAS9900)	193 KW[a]	14300	12500	0.25	1200	2000	12.10	4.19	40.54
Drying (capacity 15t@) 0.5% MC/hr), MC of 3 ton decrease from 18 to 13%	30KW (990)	1340	8000	2.00	250	2000	15.00	5.62	50.25
Baling & transportation	75KW (6403)	3880	12500	0.86	1500	2000	16.07	8.72	53.83
Freight (3t, capacity @17ton@30min)	160KW (1710D)	8800	12500	0.04	6000	2000	1.77	1.57	5.93
Total emission of CO_2e (kg ha^{-1}) from maize cropping in every cropping year								46.72	257.01
Total emission of CO_2e (kg ha^{-1})from peanut and maize alternate cropping in 30 years								1910.03	13272

Spotted gum plantation									
Deep ripping & hilling	168KW (8330)	10771	12500	1.25	1180	2000	52.50	17.42	175.88
Self propelled sprayer (4 at age 1 & 1 at 2)	92KW (7520)	6277	12500	0.32	571	2000	-	2.43	-
Seedling transport 1000@400gm @17ton)	160KW (1710D)	8800	12500	0.07	6000	2000	2.96	2.63	9.92
Slashing (3 times at age 1,2&3)	75KW (6403)	3880	12500	0.32	900	2000	6.00	2.34	20.10
Non-commercial thinning									
Felling (power chain (PC) saw) (CS71)	3.3 KW engine	6.63	8000	11.03	0	0	9.10	0.09	30.48
Commercial thinning									
Felling, limbing & bucking (PC saw-CS71)	3.3 KW engine	6.63	8000	14.7	0	0	12.13	0.12	40.63
Skidding (grapple skidder with tractor)	168KW (548G)	10768	12500	6.25	0	0	262.50	51.69	879.38
Loading/unloading transportation ti mill	160KW (1710D)	8800	12500	7.45	6000	2000	298.00	264.91	998.30
Final Harvesting									
Felling (Bouncher)	168KW (843J)	10771	12500	2.96	3012	2000	118.40	67.28	396.64
Delimbing & bucking (PC saw-CS71)	3.3 KW engine	6.63	8000	12.50	0	0	10.31	0.10	34.55
Skidding (grapple skidder with tractor)	168KW (548G)	10768	12500	10.42	0	0	437.64	86.17	1466.09
Cross cutting (PC saw CS71)	3.3 KW engine	6.63	8000	6.25	0	0	5.16	0.05	17.27
Loading/unloading transportation to mill	160KW (1710D)	8800	12500	28.26	6000	2000	1130.40	1004.88	3786.84
Total emission of CO2e (kg ha^{-1})from plantation in 30 years								1500.10	7856.07
Pasture									
Slashing (4 times at age 1,8,16&24)	75KW (6403)	3880	12500	0.35	900	2000	8.00	2.54	26.80
Deep ripping(4 times at age 1,8,16 & 24)	168KW (8330)	10771	12500	2.35	1180	2000	98.80	32.78	330.98
Discing (4 times at age 1,8,16 & 24)	92KW (8330)	6277	12500	1.87	2504	2000	42.92	31.42	143.78
Self propelled sprayer (4 times)	92KW (7520)	6277	12500	0.26	571	2000	-	1.95	-
Planting/seeding(4 times at 1,8,16 & 24)	92KW (7520)	6277	12500	1.65	1219	2000	38.04	17.65	127.43
Freight to selling yard (30 times)	160KW (1710D)	8800	12500	1.01	6000	2000	40.20	35.74	134.67
Electricity for water pumping (516 kwhr * 0.411 kgCO2e per Kwhr)									212.07
Total emission of CO2e (kg ha^{-1}) from pasture in 30 years								122.08	975.74

Note: All machineries and accessory equipment, except where indicated, were from John Deere, [22] [a] vehicle and equipments from AMADAS. [23] Fuel for self propeller (for agrochemicals) not considered (comes under agrochemicals). When the fuel consumption data unavailable, it was derived from work hour & power of machine (fuel consumption = Power of machine in KW * 0.25 L hour^{-1} * hour used) (Harris) [21]