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Comparative Analysis of Energy Requirement in the Zero Budget Natural Farming (ZBNF) and Non-ZBNF Method

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Abstract:

Conventional agricultural practices are energy intensive with heavy reliance on fossil-based fuels. Consumption of fossil energy results in direct and indirect environmental and human health hazards. With a focus on climate change, realization of adverse impacts of chemical farming and over exploitation of natural resources, natural farming practices is being promoted and advocated. While energy consumption of conventional practices is well documented, for natural farming it is much less known. Therefore, it is pertinent to study energy efficiency and consumption patterns of such farming practices. The study aims to throw light on energy consumption patterns and would help in advocating methods of cultivation from energy consumption perspective.

Executive Summary

Almost all activities in the food system depend on some form of energy, which is currently mainly provided by fossil fuels. The need to use scarce natural resources efficiently, reduce greenhouse gas emissions, minimise energy costs and foster the competitiveness of the agro-food sector highlights the importance of the energy efficiency issue: using less energy to provide the same level of output and services. Improving the energy-use efficiency of the agro-food chain is a key priority in several countries and a core element of green growth strategies. Food production is the largest user of water globally. It is responsible for 86% of consumptive water use from surface water and groundwater. Energy is a vital input for food production. It is needed for land preparation, fertilizer production, irrigation, harvesting and transportation of crops. Food production and supply chains are responsible for around 30% of total global energy demand. Increasing dependence on energy usage (mainly fossil fuels) throughout the entire food chain raises concerns about the impact of high or variable energy prices on production costs, competitiveness, the final price of food for the consumer, as well as concerns about energy security. Therefore, there is a need to move away from conventional agricultural practice and adopt efficient methods of productions.

Zero budget natural farming (ZBNF) – a sustainable agricultural system – is one such alternative to chemical fertiliser-based agriculture and high input cost agriculture. It exemplifies agro ecological principles where the emphasis is on “enhanced soil conditions by managing organic matter and soil biological activity; diversification of genetic resources; enhanced biomass recycling; and enhanced biological interactions” (Khadse, et al. 2018). The practice advocates 100 per cent elimination of synthetic chemical inputs (fertiliser and pesticides) and encourages the application of natural mixtures made using cow dung, cow urine, jaggery, pulse flour etc., mulching practices, minimum tillage and symbiotic intercropping.

Thus, ZBNF is low-input, climate-resilient type of farming that encourages farmers to use low cost locally-sourced inputs, eliminating the use of chemical fertilizers and industrial pesticides. By eliminating the use of chemical fertilisers and pesticides, and reducing the usage of mechanised devices and motorised water pump, ZBNF has the potential to vastly reduce the need for, and use of energy along their value chain.

Towards this, the paper aims to compare energy consumption and efficiency of conventional methods of agricultural practices involving use of chemicals, fertiliser and insecticides and natural practices of ZBNF by analysing energy value of inputs and output.

Sampling and Data

We surveyed 200 farmers across four districts of Andhra Pradesh to estimate reductions in energy consumption. The districts sampled were Anantapur, Chittoor, Guntur, Kurnool, It is based on the predominant crop and irrigation pattern of farming practices. Minimum landholding size of farmer should be greater than 1 acre. The questionnaire consisted of different segments to collect data on land holding patterns, crop grown, use of fuel in machineries and equipment and hours of operations each day, source of water supply, use of inputs such as pesticides and fertilisers (chemical and bio inoculums), use of labour including gender and output including yield and market price realised.

Methodology

From the collected data, the relevant inputs were converted into energy terms (MJ/acre). For instance, if the farmer used a tractor for 5 hours in the entire cropping cycle consuming 3 litres of diesel per hour, then it implied that 15 litres of diesel was consumed. The diesel in litre was multiplied by the energy coefficient of per litre of diesel which was sourced from the literature on energy. One litre of diesel has energy equivalent of 53.6 Mega Joule. Therefore, total 717 Mega Joule of energy consumed for land preparation. In the same way energy consumption of all the chemicals, non –chemicals, electrical units and fuels would be converted into energy equivalent. After findings the quantitative values of energy equivalent, comparative study between ZBNF and Non-ZBNF has been done.

Anantapur

Energy consumption of mechanized devices in ZBNF is estimated to be 32% lower than non-ZBNF while for fertilisers it is 23% lower. Overall, energy consumption is 24% lower in ZBNF (13,937.20 MJ/Acre) compared to non-ZBNF (18,337.51MJ/Acre) in groundnut cultivation. ZBNF being a labour-intensive process, energy in terms of labour is 10% higher than non-ZBNF. On the output side, the estimations suggest that yield in ZBNF practices is 10% higher than non-ZBNF.

Difference between Specific Energy Consumption (SEC) Ratios is significantly high for non-ZBNF compared to ZBNF. While input wise SEC Ratio of non-ZBNF and ZBNF is 16.11 and 11.20 respectively, which shows ZBNF is more energy efficient compares to non-ZBNF.

Chittoor

Energy consumption in use of mechanized devices in non-ZBNF practice is 11% higher than ZBNF while the consumption of labour energy is 8% higher in ZBNF. Total energy of inputs in non-ZBNF practice is 19,475 MJ/acre while for ZBNF it is 21% lower at 15,425MJ/acre. The yield in ZBNF is 13% higher than other farming practices while the ZBNF farmers get a price premium of 20%. Estimations suggest that low input costs along with higher yield and price premium, translates into 36% higher income for ZBNF farmers on a per acre basis.

Despite marginally higher energy input consumption of mechanized device in ZBNF, its SEC Ratio is lower than non-ZBNF indicating efficient utilization of the resource (0.54 vs. 0.42). Similarly, the SEC ratio of other variables is also lower for ZBNF than in non-ZBNF except for labour. For labour, the ratio is virtually equal for both kinds of practices at 1.65. Overall SEC ration of ZBNF is lower than non-ZBNF by 2.60.

Kurnool

Total energy of input for non-ZBNF is 24,162 MJ/acres while for ZBNF it is 27% lower at 17,627 MJ/acres. Fertiliser is the biggest component of energy use in both the forms of practices while the share of irrigation in total energy consumption is marginally lower for ZBNF. In absolute terms, energy consumption attributable to irrigation and fertiliser 30% and 28% lower respectively in ZBNF while energy input in form of labour is 17% higher in ZBNF.

Total SEC ratio for non-ZBNF is 24.80 while for ZBNF it is 15.38 which is implies efficient use of resources in ZBNF practices.

Guntur

Energy consumption attributable to irrigation and mechanization are 30% and 29% less in ZBNF than in non-ZBNF respectively while energy of human labour used in ZBNF is 13% more than that in non-ZBNF. Yield of chillies under ZBNF practices have been reported to be 21% more than non-ZBNF (3296 kg/acre vs 2720 kg/acre) while ZBNF produce fetches a price premium of ₹4.04/kg leading to 26% more gross income to ZBNF farmers than for non-ZBNF farmers. The overall SEC ratio for non-ZBNF is 28.01 while for ZBNF it is 13.59.

Energy Savings Potential in ZBNF

From the findings of the study, it can be clearly observed that energy consumption in ZBNF is much less than in non-ZBNF indicating a substantial potential for energy savings. Estimations suggest that nearly 4557984.60 MJ of energy can be saved if all the non-ZBNF farmland under study is converted to ZBNF. In energy terms, it is equivalent to saving 95,355 litres of diesel. While on an average 2622.48 MJ/acre of energy saving potential exists.

On average, energy consumption attributable to fertiliser consumption can be reduced by 9922 MJ/acre while operating hours of mechanized devices would undergo reduction from 23.92 hours under non-ZBNF to 5.98 hours per cropping cycle in ZBNF implying substantial savings in direct fuel consumption. Use of human labour is expected to increase by 8% per acre on average indicating sustained and increased economic opportunities.

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Introduction

Agriculture, as a sector requires energy as an important input to production (Clark W. Gellings, 2009). It is itself an energy conversion process, converting solar energy into food energy for humans and animals through photosynthesis. In the evolution from traditional to modern agriculture, use of commercial energy has increased sharply. On the input side, there is substantial increase in the use of modern inputs and farm mechanization, leading to high energy consumption. Rapid expansion of tube well irrigation and increased consumption of phosphates and potassium fertilizer coupled with increasing commercialization and diversification towards high value crops have led to indiscriminate and injudicious use of resources. These developments have had significant implications for energy use in agriculture as they require high quantities of commercial energy. Thus, high energy consumption in agricultural inputs will compromise food security for future generations due to limited availability of energy resources (Hamdollah E, 2015).

Agricultural intensification through the use of high-yielding variety crops, fertilisers, irrigation and other chemicals has resulted in severe environmental and ecological degradation of the farming ecosystem including soil health and erosion, effectively rendering the agro ecology energy inefficient (Alipour A., 2012). Furthermore, with the visible effects of climate change, energy scarcity and food production challenges, new forms of sustainable agricultural practices are being developed with the combination of technology and indigenous knowledge. Therefore, there is urgent need to find out the ways of conserving energy. Reducing tillage operations, efficient management of crop residues, irrigations, nutrients, pesticides and all other inputs will help to conserve energy in agriculture. One of them is 'Zero Budget Natural Farming' (ZBNF).

ZBNF is a form of farming practice involving crop rotations and intercropping with minimal use of external resources and inputs. Built on traditional practices, it is based on 4 pillars viz. (1) *beejamrutham*, or microbial coating of seeds using cow dung and urine based formulations; (2) *jeevamrutham*, or the application of a bioinoculum made with cow dung, cow urine, jaggery, pulse flour, water and soil to multiply soil microbes; (3) *mulching*, or applying a layer of organic material to keeping the ground temperature cooler and reducing evaporation, it can lessen nutrient volatilization (National Academy of Agriculture Sciences , 2019); and (4) *waaphasa*, or soil aeration through a favourable microclimate in the soil. Plant protection measures include a mixture of butter milk, cow milk, pepper powder, neem seed and green chillies. Thus, ZBNF is low-input, climate-resilient type of farming that encourages farmers to use low cost locally-sourced inputs, eliminating the use of chemical fertilizers and industrial pesticides. By eliminating the use of chemical fertilisers, pesticides and reducing the usage of mechanised devices and motorised water pump, ZBNF has the potential to vastly reduce the need for, and use of energy along their value chain.

Similarly, use of locally available resources would lead to effective use of scarce resources. Therefore, examining the energy of inputs consumed in the agricultural practices can help us understand energy efficiency of the systems and methods being practiced.

Towards this, the study aims to compare energy consumption and efficiency of conventional methods of agricultural practices involving use of chemicals, fertiliser and insecticides and natural practices of ZBNF by analysing energy value of inputs and output. The next section of the paper involves literature review, which is followed by methodology, findings, discussions and conclusion.

Literature Review

In agriculture, energy is important in terms of crop production and agro-processing for value adding (Ozkan B., 2004).In the evolution from traditional to modern farming, the commercial energy use has increased sharply (Zoghipour A., 2011) (Iqbal, 2007). This led to enormous impacts on natural environment e.g. degradation and erosion of the soil structure, and environmental pollution brought about carbon dioxide emissions, loss of quality food and risk of their toxicity. As a result, these systems reduced energy efficiency more than traditional systems making this system not stable and sustainable instability of these systems (Zoghipour A., 2011).

Energy requirements in agriculture are divided into two groups – direct and indirect. Direct energy is required to perform various tasks related to crop production processes such as land preparation, irrigation, inter-cropping; threshing, harvesting and farm produce (J.M, 2000). Indirect energy, on the other hand, consists of the energy used in the manufacture, packaging and transport of fertilizers, pesticides and farm machinery (CAEEDAC, 2000). As the term addresses, indirect energy is not directly used on the farm. Major items for indirect energy are fertilizers, seeds, machinery production and pesticides. When a natural system capable of producing a certain amount of energy containing biomass is converted into agro-products, the natural capability limit is often exceeded by adding energy inputs. The greater the input of external energy, the more the natural capability of the system can be exceeded, and the less sustainable the system becomes. (Farshad A., 2001) Because of this relationship, an analysis of agro-ecosystem's input/output energy balance can be a comprehensive indicator of its sustainability (Farshad A., 2001). In this regard, efficient use of energy by the agriculture sector seems as one of the conditions for sustainable agriculture because it allows financial savings, fossil resources conservation and air pollution reduction. (Pervanchon F., 2002).

The energy coefficients of these direct and indirect energy sources are available in the papers (Seyyedhassan Pishgar-Komleh), (Alipour A., 2012), (Gagandeep Kaur, 2017). The energy coefficients used in this study are given in Table 1. For example, fossil fuels can be partly converted to thermal energy by combustion. Energy coefficients are standard conversion factors for indicating energy content in a matter or as the capacity to do work by different sources. The international unit (SI unit) of energy is joule (J). Some non-SI units are also used to express energy like calorie as energy stored in foods (1 cal =4.187 J), kilogram force meter (1 kg f m = 9.8 J) as energy unit stored by a body of 1 kg raised at 1 m height, kilowatt hour (1 kWh= 3.6 *106 J) as energy consumed or generated by electricity and horse power hour (1 HPh=2.686 *106 J). In principle, the energy content of a source is known when the source is specified. The direct energy source like fuel is represented by its chemical energy, and the energy content or coefficient is given as the calorific value or heating value of that fuel, expressed in mega joule/kilogram or mega joule/litre (1 MJ=10^6 J kg).

Methodology

Primary survey was conducted in the districts of Andhra Pradesh for the purpose of the study. For each major crop namely, paddy, cotton, chillies and groundnuts, the district with high production of the crops was selected and 50 farmers were surveyed for each crop in the respective districts (25 ZBNF and 25 Non-ZBNF). Production data was sourced from state and central governments published data. The table 1 presents the crop cultivated and the corresponding district where the survey was administered.

Table 1: Districts Surveyed and Major Crop Cultivated

District	Crop
Anantapur	Groundnuts
Kurnool	Cotton
Guntur	Chillies
Chittoor	Paddy

The questionnaire consisted of different segments to collect data on land holding patterns, crop grown, use of fuel in machineries and equipment and hours of operations each day, source of water supply, use of inputs such as pesticides and fertilisers (chemical and bio inoculums), use of labour including gender and output including yield and market price realised. From the collected data, the relevant inputs were converted into energy terms (MJ/acre). For instance, if the farmer used a tractor for 5 hours in the entire cropping cycle consuming 3 litres of diesel per hour, then it implied that 15 litres of diesel was consumed. The diesel in litre was multiplied by the energy coefficient of per litre of diesel which was sourced from the literature on energy. Similar exercise was undertaken from other inputs including fertilisers, pesticides, herbicides, human labour, irrigation and other inputs. Since the energy equivalent for farmlands relying solely on rain for irrigation and not using any pump or mechanical devices cannot be ascertained, value of '1' was allotted to the irrigation variable for such farmlands. To convert the complex fertilisers in energy terms, combination of commonly used NPK (DAP, SOP, etc) fertilisers were sourced from literature for each crop. Ratio of potassium and phosphate was ascertained in K_2O and P_2O_5 which was used to determine the energy coefficient of each nutrient. The coefficient was then multiplied to the quantity used by the farmer and the ratio of nutrient in the fertiliser. For instance, Single Super Phosphate (SSP) fertiliser used includes 14.5% phosphate (Narmada Bio-Chem Ltd).Therefore, 14.5% of energy value of P_2O_5 was assigned to SSP fertiliser. The table 2 below indicates the energy coefficient assumed for each energy consuming variable.

Table 2: Energy Conversion Coefficients

Input	Energy Coefficients (MJ/Unit)	Source
Diesel (L)	47.8	(Pishgar-Komleh, Sefeedpari, & Rafiee, 2011)
Fertilisers		
N (kg)	78.1	(Pishgar-Komleh, Sefeedpari, & Rafiee, 2011)
P_2O_5 (Kg)	17.4	(Pishgar-Komleh, Sefeedpari, & Rafiee, 2011)
K_2O (Kg)	13.7	(Pishgar-Komleh, Sefeedpari, & Rafiee, 2011)
Insecticides (Kg)	119	(Ferro, Zanin , & Borin, 2017)
Human Labour (hours)	1.58	(Ferro, Zanin , & Borin, 2017)
Manure (kg)	0.33	(Ferro, Zanin , & Borin, 2017)
Paddy (Kg)	17	(Pishgar-Komleh, Sefeedpari, & Rafiee, 2011)
Cotton (kg)	11.8	(Dağistan, Akcaoz, Demirtas, & Yilmaz, 2009)
Groundnut (Kg)	37.5	(Kumar, Anantchar, Guruswamy, & Kawale, 2005)
Chillies (Kg)	1.68	(Nutrition and You)

To assess the impact of inputs on yield of the crop, a regression analysis was undertaken. Following a method of Ordinary Least Square (OLS), regression coefficients were estimated for different mathematical functions including linear and polynomial were tested. Based on our results and research in the literature of the field, logarithmic mathematical function was chosen (Alipour A., 2012) (Ferro, Zanin , & Borin, 2017). For some variables the data was zero (for instance, if the field is rain fed, the irrigation data was 0). However, since log of 0 is undefined, the data was assumed to be "1". Since log of 1 is 0, the method does not impact the results (CEEW, 2019). The form can be expressed as:

$$log\, Y_i = log\beta_0 + \beta_j \sum_{j=1}^{n} logX_{ij} + e_i$$

Where,

Y_i = Yield of the i^{th} farmer
X_{ij} = Vector of inputs used in the production process.

Table 3: Description of Explanatory Variables

Input Variables	Description
Land holdings	Medium & Large Landholders = 1 (Land holders having agricultural land of at least 5 acres) Small & Marginal Landholders = 0
Agricultural Practices	ZBNF = 1 (Those practicing "Zero Budget Natural Farming") Non-ZBNF = 0
Land holding x Agricultural Practices	Medium & Larger Landholders practicing ZBNF = 1 Medium & Large Landholders practicing non-ZBNF=0
Mechanization	Mechanical devices, machineries and equipment except for irrigation consuming fuel used in an agricultural cycle
Labour	Human labour used in an agricultural cycle
Fertilisers	All forms of organic and chemical fertilisers used. ZBNF farmers uses only organic fertilisers while non-ZBNF farmers use chemical fertilisers
Insecticides	Used by non-ZBNF farmers. ZBNF method do not advocate use of insecticides.
Irrigation	Pumps and machines used for irrigation (canals and underground). Value is 0 if only rainfall used as a source of water.

β_0 = Intercept term

β_j = Estimated regression coefficient

e_i = Error Term

Since, dummy variables can incorporate categorical data in the model, agricultural practice and land holding were included as dummy variables in the model. Agricultural practice has been defined as ZBNF and non-ZBNF practice where ZBNF= 1 and non-ZBNF=0. Land holding has been defined as small & marginal farmers and medium and large farmers where small and marginal farmers=0 and medium & large farmers= 1. Based on definition of Government of India, farmers having land holdings smaller than 5 acres are small & marginal farmers. To further assess the joint impact of ZBNF and medium & large land holding, an interactive term was also incorporated. Since the regression model used is of the log-log form, to interpret the coefficients of dummy variables, the exponential of the coefficients was taken.

Specific Energy Consumption (SEC) Ratio has also been estimated to gauge the efficiency of input i.e. how much input in energy terms is required to produce per unit of output. The metric is widely used in the literature to test the efficiency of a system (Ferro, Zanin , & Borin, 2017) (Alipour A., 2012). Following formula has been used to estimate the ratio:

$$SEC\ Ratio = \frac{Energy\ Input\ (MJ/Acre)}{Output\ (kg/acre)}$$

Results and Discussions

The data was separately collected for non-ZBNF and ZBNF practices. Total of 434.51 acres of landholdings were covered across the districts of which 194.63 acres (45%) were under ZBNF practices. On an average 24% of the land holding surveyed can be classified as small and marginal farmers while significant variations in landholding patterns were observed across crops.

Table 4: Land Holding Patterns (%)

	Kurnool		**Chittoor**		**Guntur**		**Anantapur**	
Category of Farmer	ZBNF	Non-ZBNF	ZBNF	Non-ZBNF	ZBNF	Non-ZBNF	ZBNF	Non-ZBNF
Marginal	40	4	32	4	12	32	12	12
Small	32	68	28	44	36	28	36	52
Semi-Medium	20	28	40	40	52	40	48	28
Medium	8	0	0	12	0	0	4	8
Large	0	0	0	0	0	0	0	0

For instance, of the total landholding under survey for cotton crop for ZBNF, 72% were small and marginal farmers while for groundnuts it was 48%. This variation indicates that depending upon the crop and it's farming characteristics, ZBNF has been adopted by all classes of farmers and not only by small and marginal farmers.

Table 5: Energy consumption per acre in ZBNF and non-ZBNF

District	**Crop**	**Non-ZBNF(MJ/acre)**	**ZBNF(MJ/acre)**	**% Change over Non-ZBNF**
Anantapur	Groundnut	18,337	13,937	24
Chittoor	Paddy	19,475	15,425	21
Guntur	Chillies	76,227	44,811	41
Kurnool	Cotton	24,162	17,627	27

The amount of energy consumption decreases per acre in ZBNF varies from 4050 MJ to 31416 MJ. The highest energy consumption occurs in Chillies and lowest in paddy. This happens because the water requirement in paddy in ZBNF doesn't have significant decrease as compared to other crops selected in the study.

Table 6: Yield in ZBNF and non-ZBNF

District	Crop	Non-ZBNF (Kg/Acre)	ZBNF (Kg/Acre)	% Change over Non-ZBNF
Anantapur	Groundnut	1138	1248	10
Chittoor	Paddy	2253.8	2553.3	13
Guntur	Chillies	2720	3296	21
Kurnool	Cotton	974.1	1146	18

All the crops selected for study has significant increase in yield. The highest amongst all is chillies, increased by 21%.

Table 7: Gross Income in ZBNF and non-ZBNF

District	Crop	Non-ZBNF (₹/Acre)	ZBNF (₹/Acre)	% Change over Non-ZBNF
Anantapur	Groundnut	51118.9	58840.7	15
Chittoor	Paddy	34618.2	47252.9	36
Guntur	Chillies	214080	240250	13
Kurnool	Cotton	47302.1	59248.2	25

As yield increases in all the crops, which enhances the farmer income, which varies from 15% to 36%. The lowest among all is Groundnuts, as Groundnuts has the lowest growth in Yield Table 7 i.e. 10%. The increase in gross income has also happened, because farmers are getting premier price over non-ZBNF.

Table 8: Cost of Fertiliser/Kasayam

District	Crop	Non-ZBNF (₹/Acre)	ZBNF (₹/acre)	%Change over Non-ZBNF
Chittoor	Paddy	6944	2065	70
Anantapur	Groundnut	7872	2247	71
Kurnool	Cotton	7552.5	2343	69
Guntur	Chillies	11034	4033	64

Fertilizer consumes major portion of farmers input cost in case, of natural farming practices. The input cost of fertiliser decreased by almost one-third in all the selected crops for the study. The cost of ZBNF Kasayam is calculated, if the farmer purchases cow urine, cow dung and other material from Non Pesticidal Management shops or from other source. In case of, farmer having their own *desi* cow, the cost of Kasayam further reduce.

The table 4 below presents the results of the regression analysis.

Table 9: Results of Regression Analysis

Crop	Groundnut	Paddy	Cotton	Chillies
District	**Anantapur**	**Chittoor**	**Kurnool**	**Guntur**
R^2	0.65	0.52	0.57	0.51
No. of Observations	50	50	50	50
Intercept	4.362 (0.42)	4.508 (0.34)	4.156 (0.64)	3.560 (1.27)
Medium & large landholders	-0.014* (0.01)	-0.075* (0.02)	-0.062 (0.54)	0.006 (0.02)
ZBNF	0.075* (0.23)	0.002 (0.27)	-0.011 (0.05)	0.418* (0.67)
Medium & large landholders x ZBNF	0.016* (0.02)	0.095* (0.02)	-0.017 (0.05)	-0.035* (0.03)
Mechanization	0.063* (0.08)	0.009* (0.08)	0.007 (0.05)	0.189* (0.09)
Labour	0.031 (0.03)	0.061* (0.03)	0.092* (0.05)	-0.025* (0.10)
Fertilisers	-0.013* (0.01)	0.081* (0.05)	0.079* (0.07)	0.053 (0.16)
Insecticides	0.002 (0.08)	-0.001 (0.094)	-0.04 (0.17)	0.098 (0.19)
Irrigation	0	0	0.005* (0.06)	0.013* (0.01)

*Significant at 5% level of significance

Anantapur

From the table it can be observed that irrigation is non-existent in the district and thus, all the farmers rely on rainfall. The exponential of coefficient of medium & large land holders indicates that yield is 0.97% (coefficient= -0.014, exp coefficient= -0.97) lower for large land holders than small and marginal farmers. It can be due to lack of irrigation infrastructure in the district as impact of less than required rainfall is greater on big farmers than in the case of small farmers. Those practicing ZBNF has 1.07% higher yield compared to non-ZBNF practitioners. The yield of large land holders practicing ZBNF is 1.01% higher than larger land holders practicing non-ZBNF. Given the results, it should be noted that lower yield as captured by medium & large land holder variable is primarily due to non-ZBNF practices. Ceretis paribus, 1% increase in use of mechanized devices, labour and pesticides increases yield by 0.063%, 0.031% and 0.002% respectively, while increasing fertiliser by 1% decreases yield by 0.013%. All the variables apart from labour, insecticides and irrigation are statistically significant at 5% level of significance.

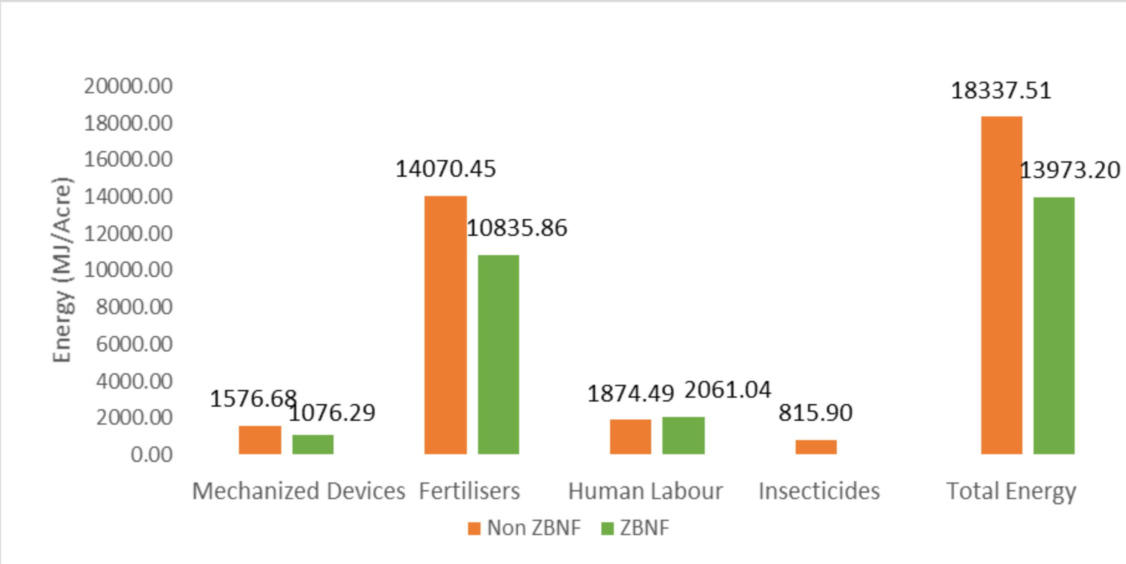

Figure 1: Input wise Energy Consumption (Groundnut)

Fertilisers, chemical for non-ZBNF and natural for ZBNF, form the largest component of total energy of input, followed by labour and mechanized devices. Energy consumption of mechanized devices in ZBNF is estimated to be 32% lower than non-ZBNF while for fertilisers it is 23% lower. Overall, energy consumption is 24% lower in ZBNF (13,937.20 MJ/Acre) compared to non-ZBNF (18,337.51MJ/Acre) in groundnut cultivation. ZBNF being a labour-intensive process, energy in terms of labour is 10% higher than non-ZBNF. On the output side, the estimations suggest that yield in ZBNF practices is 10% higher than non-ZBNF. No insecticides and pesticides are used in ZBNF. Estimates indicate that ZBNF farmers command a price premium of 5% over non-ZBNF farmers.

Difference between Specific Energy Consumption Ratio is significantly high for non-ZBNF compared to ZBNF. While input wise SEC Ratio is presented in the table below, overall, SEC Ratio for non-ZBNF is 16.11 over 11.20 for ZBNF. Clearly, most of the inputs are much more efficiently used in ZBNF practices.

Table 10: SEC Ratio (Groundnuts)

	Non-ZBNF	ZBNF
Mechanized Devices	1.38	0.86
Fertilisers	12.63	8.68
Human Labour	1.64	1.65
Insecticides	0.72	0
Total	16.11	11.20

Chittoor

Yield of paddy in the district lesser by 0.92% for large farmers compared to smaller farmers. It might be so because paddy is a water intensive crop and without irrigational facilities it will be difficult to grow the crop at scale with maximum yield. Yield of ZBNF practitioners has been estimated to be 1% higher than the non-practitioners while it is higher by 1.1% for large farmers practicing ZBNF compared to non-ZBNF large farmers. Since ZBNF techniques advocates consumption of less water along with other methods, it can be the primary reason for the difference in yield in a district without much irrigation facilities. Ceretis paribus, other variables including mechanization, labour, fertilisers and irrigation were found to be positively correlated with marginal increase in yield due to 1% increase in their use. Insecticide is negatively correlated with yield but is statistically insignificant. Irrigation is another variable found to be statistically insignificant, while other variables are significant.

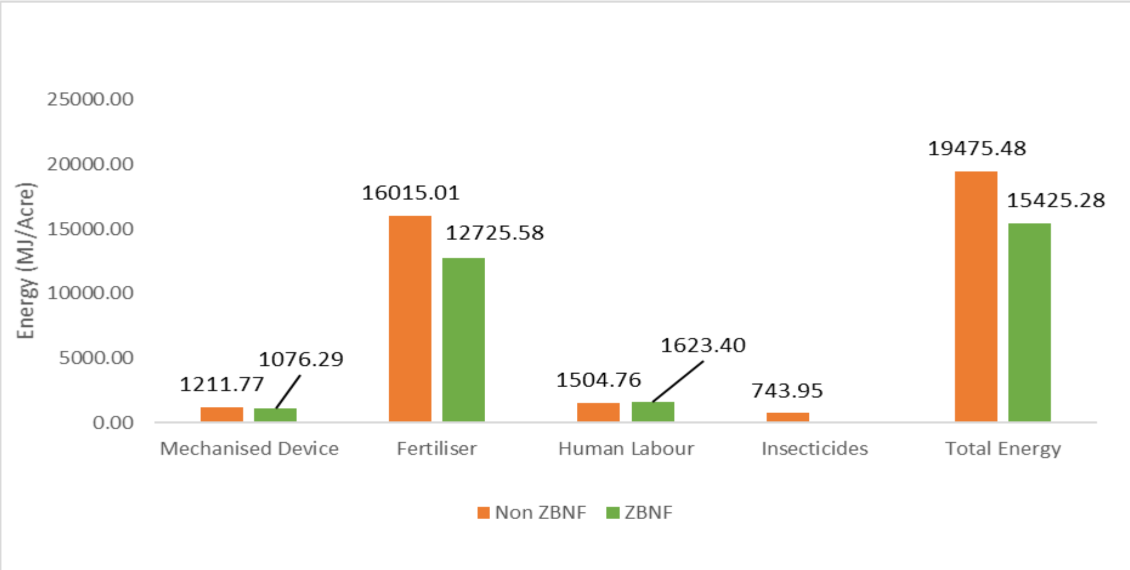

Figure 2: Input-wise energy consumption (Paddy)

Fertiliser constitutes the largest energy component in both the practices accounting for 82% of the total input energy consumption. Share of labour input in total energy of inputs is greater in ZBNF (11%) than non-ZBNF (8%). Interestingly, the share of energy consumption of mechanised devices is marginally greater in ZBNF than non-ZBN. It can be on the account of post-harvest devices that might be used. Non-ZBNF practices usually involve burning of the straw while in ZBNF straw is mulched and spread over the fields to act as a natural soil conditioner and manure upon its decomposition. However, in absolute terms, energy consumption in use of mechanized devices in non-ZBNF practice is 11% higher than ZBNF while the consumption of labour energy is 8% higher in ZBNF. Total energy of inputs in non-ZBNF practice is 19,475 MJ/acre while for ZBNF it is 21% lower at 15,425MJ/acre. The yield in ZBNF is 13% higher than other farming practices while the ZBNF farmers get a price premium of 20%. Estimations suggest that low input costs along with higher yield and price premium, translates into 36% higher income for ZBNF farmers on a per acre basis.

Despite marginally higher energy input consumption of mechanized device in ZBNF, its SEC Ratio is lower than non-ZBNF indicating efficient utilization of the resource (0.54 vs 0.42). Similarly, the SEC ratio of other variables is also lower for ZBNF than in non-ZBNF except for labour. For labour, the ratio is virtually equal for both kinds of practices at 1.65.

Table 11: SEC Ratio (Paddy)

	Non-ZBNF	ZBNF
Mechanized Devices	0.54	0.42
Fertilisers	7.11	4.98
Human Labour	0.67	0.64
Insecticides	0.33	0
Total	8.64	6.04

Kurnool

Regression analysis suggests that yield is 0.93% lower than for large & medium farmers than for small & marginal farmers while it is 1% lower for farmers practicing ZBNF over non-ZBNF farmers and 0.98% lower for large & medium farmers practicing ZBNF. However, the differences in yield are statistically insignificant. Ceretis Paribus, one percent increase in mechanized devices, fertilisers, labour and irrigation have marginal impact on yield (0.007%, 0.09%, 0.079% and 0.005% respectively) of which all but mechanization is statistically insignificant. Additional 1% increase in use of insecticides is expected to reduce yield by 0.004% and is statistically insignificant.

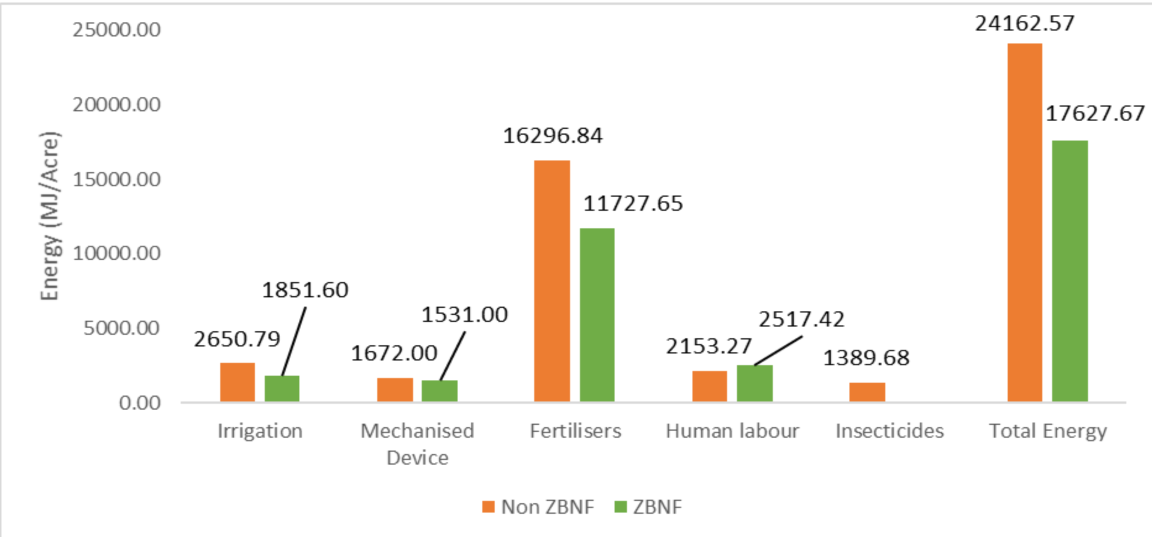

Figure 3: Input-wise Energy Consumption (Cotton)

Total energy of input for non-ZBNF is 24,162 MJ/acres while for ZBNF it is 27% lower at 17,627 MJ/acres. Fertiliser is the biggest component of energy use in both the forms of practices while the share of irrigation in total energy consumption is marginally lower for ZBNF. In absolute terms, energy consumption attributable to irrigation and fertiliser 30%

and 28% lower respectively in ZBNF while energy input in form of labour is 17% higher in ZBNF. The yield has been estimated to be 18% higher in ZBNF and the practitioners fetch a price premium of 6% for their ZBNF produce. Consequently, the income of ZBNF farmers is estimated to be 25% higher than non-ZBNF farmers. Total SEC ratio for non-ZBNF is 24.80 while for ZBNF it is 15.38 which is implies efficient use of resources in ZBNF practices.

Table 12: SEC Ratio (Cotton)

	Non-ZBNF	ZBNF
Irrigation	2.72	1.61
Mechanized Devices	1.71	1.33
Fertilisers	16.7	10.23
Human Labour	2.21	2.19
Insecticides	1.42	0
Total	24.80	15.38

Guntur

Results of the regression analysis indicate yield is 1% higher for large & medium farmers over small & marginal farmers and is statistically significant. Though statistically insignificant, ZBNF farmers have 1.5% higher yield than non-ZBNF farmers, while the yield is 0.96% higher for large & medium farmers practicing ZBNF over large & medium non-ZBNF farmers and is statistically significant. Ceritis Paribus, 1% increase in mechanization, fertilisers, insecticides and irrigation would increase the yield by 0.19%, 0.05%, 0.01% and 0.01% respectively, while 1% increase in human labour would reduce the yield by 0.03%. Coefficients of mechanization, labour and irrigation were found to be statistically significant.

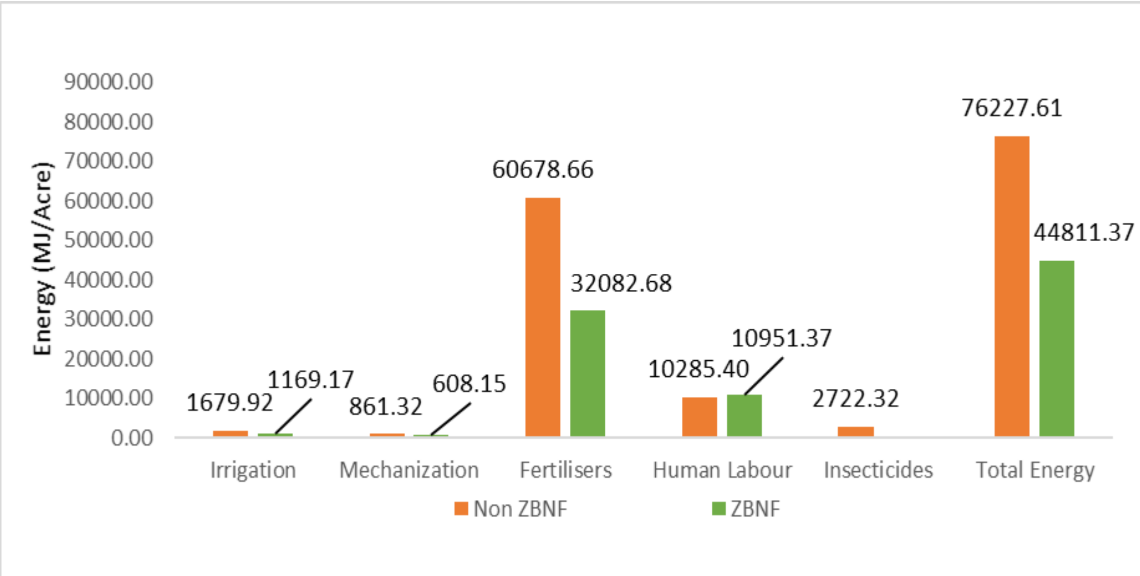

Figure 4: Input-wise Energy Consumption (Chilli)

Total energy of input consumption for chilli production in the district has been estimated to be 76,227 MJ/acre for non-ZBNF and 44,811 MJ/acre for ZBNF implying ZBNF uses 41% less energy than non-ZBNF. Fertiliser has the largest share of energy component followed by human labour in the total energy of inputs. Energy consumption attributable to irrigation and mechanization are 30% and 29% less in ZBNF than in non-ZBNF respectively while energy of human labour used in ZBNF is 13% more than that in non-ZBNF. Yield of chillies under ZBNF practices have been reported to be 21% more than non-ZBNF (3296 kg/acre vs 2720 kg/acre) while ZBNF produce fetches a price premium of ₹4.04/kg leading to 26% more gross income to ZBNF farmers than for non-ZBNF farmers. SEC ratios have been presented below in the table. The overall SEC ratio for non-ZBNF is 28.01 while for ZBNF it is 13.59.

Table 13: SEC Ratio (Chillies)

	Non-ZBNF	ZBNF
Irrigation	0.61	0.35
Mechanized Devices	0.31	0.18
Fertilisers	22.3	9.73
Human Labour	3.78	3.32
Insecticides	1	0
Total	28.01	13.59

From the findings of the study, it can be clearly observed that energy consumption in ZBNF is much less than in non-ZBNF indicating a substantial potential for energy savings. Estimations suggest that nearly 4557984.60 MJ of energy can be saved if all the non-ZBNF farmland under study is converted to ZBNF. In energy terms, it is equivalent to saving 95,355 litres of diesel. While on an average 2622.48 MJ/acre of energy saving potential exists, the table below highlights the energy saving potential of each district for the area under study.

Table 14: Energy Saving Potential

District	Crop	Area under Non-ZBNF (in acres)	Energy Saving Potential (MJ)
Chittoor	Paddy	94.8	339963.60
Kurnool	Cotton	96	493941.26
Anantapur	Groundnuts	130	461293.91
Guntur	Chillies	113.71	3262785.82
Total		**434.51**	**4557984.60**

On average, energy consumption attributable to fertiliser consumption can be reduced by 9922 MJ/acre while operating hours of mechanized devices would undergo reduction from 23.92 hours under non-ZBNF to 5.98 hours per cropping cycle in ZBNF implying substantial savings in direct fuel consumption. Use of human labour is expected to increase by 8% per acre on average indicating sustained and increased economic opportunities. Shifts in use of factors of production are likely to change socio-economic characteristics of the region. One of the aims of ZBNF programme in Andhra Pradesh is to utilise women's self-help groups for scaling and sustaining farm and non-farm activities under the programme (CEEW, 2018). Engagement of women workforce in the economic opportunities arising due to transformation towards ZBNF would promote economic and social equality and well-being.

Other studies pertaining to ZBNF has also reported increase in yield and income over non-ZBNF practices. One of the studies undertaken by the Council on Energy, Environment and Water estimated 51% (vs 36% estimate of this study) increase in income of the paddy farmers practicing ZBNF over non-ZBNF (CEEW, 2018). Another study on ZBNF v/s non-ZBNF reported 14% (vs 10% estimate of this study) and 30% increase in yield of groundnuts and maize respectively (Dharmendar, 2019). These studies along with other corroborates with the findings of this paper and further establishes the empirical evidence of increase in yield and income (due to price premium and reduced input costs) in ZBNF farming over other methods of agricultural systems.

Conclusion

Given the limited resources available with mankind, it is extremely important to use resources effectively and efficiently. With this regard, the paper tries to assess input and outputs of ZBNF and Non-ZBNF agricultural practices with respect to energy. The study was undertaken in the select districts of Andhra Pradesh for major crops namely cotton, paddy, ground nuts and chillies. The findings point out substantial energy saving opportunity and socio-economic well-being if the agricultural practices are to shift to ZBNF. Unlike conventional methods which propagate economies of scale, ZBNF is equally effective and efficient across all land holding sizes. Therefore, ZBNF can be touted as an energy efficient and effective method of farming over non-ZBNF irrespective of land holding size. This is a significant observation in the light of Agricultural Census 2015-16 which reported that 86.08% of the land holdings belonged to small and marginal farmers (Government of India, 2019).

Apart from energy savings and increased income, transition to ZBNF would have significant economic benefit in terms of savings of subsidies distributed for chemical fertilisers. Fertiliser is the most significant input energy amongst all the input considered for the study. A study estimated potential savings of ₹ 2,154 crores if all the farmers in the state of Andhra Pradesh (CEEW, 2020). Therefore, it is recommended to shift farming methods towards ZBNF which consumes much less of fertilisers over other methods.

Advocating and promoting the practices through awareness campaign and word of mouth would enable faster adoption of the practices. Inclusion of Self-Help Groups as key stakeholders would help in quick mass mobilisation for training and capacity building of farmers. Apart from costs, yield and income, energy efficiency should also be a key metric in measuring the impact of ZBNF. Along the lines of organic certification, natural certification should also be developed which at a later stage can be linked to carbon markets. This would ensure development of a robust market mechanism along the value chain from input to output.

Given the limited scope and resources available for the study, the report is preliminary in nature and further scientific studies may be undertaken to better understand the linkages between consumption of energy in form of inputs and agricultural practices. The sample size is a limitation of the study. In all, 200 farmers were surveyed while the district and the state have much larger population practicing farming. Furthermore, other variables affecting yield such as temperature, experience of the farmer, geographical proximity to the input and the output and others were not considered in the study.

REFERENCES:

Alipour A., V. H. (2012). *Study and determination of energy consumption to produce conventional rice of the Guilan province.*

Arizpe, N., Giampietro, M., & Ramos-Martin, J. (n.d.). *Food Security and Fossil Energy Dependence.*

CAEEDAC, 2. (2000). *A Descriptive analysis of energy consumptionin agriculture and food sector in Canada.*

CEEW. (2018). *Zero Budget Natural Farming for the Sustainable Development Goals.*

CEEW. (2019). *The Potential for Savings in the Paid Out Cost of Cultivation and Fertiliser Subsidies.*

CEEW. (2020). *Can ZBNF Save Input Costs and Fertilisers Subsidies?*

Clark W. Gellings, K. E. (2009). *ENERGY EFFICIENCY IN FERTILIZER PRODUCTION AND USE.*

Dağistan, E., Akcaoz, H., Demirtas, B., & Yilmaz, Y. (2009). Energy usage and benefit-cost analysis of cotton production in Turkey . *African Journal of Agricultural Research*.

Dharmendar, G. R. (2019). *Andhra Pradesh 'Zero-Budget' Natural Farming: Vision 2024: A Systemwide Transformation.*

Farshad A., Z. J. (2001). *Assessing Agricultural Sustainability Using the Six-Pillar Model.*

Ferro, N. D., Zanin , G., & Borin, M. (2017). Crop yield and energy use in organic and conventional farming: A case study in North East Italy. *European Journal of Agronomy*.

Gagandeep Kaur, Y. S. (2017). *Potential of Livestock Generated Biomass: Untapped Energy Source in India.*

Government of India. (2019). *Agriculture Census 2015-16.*

Hamdollah E, S. (2015). *Energy comparison of two rice cultivation systems.*

Iqbal, M. (2007). *Energy input and output for production of Boro rice in Bangladesh.*

J.M, S. (2000). *On farm energy use pattern in different cropping systems in Haryana, India.*

Kumar, V., Anantchar, M., Guruswamy, T., & Kawale, N. (2005). Energetics of Groudnut Productionin Red Soil. *Karnataka Journal of Agricultural Science*.

Narmada Bio-Chem Ltd. (n.d.). *SSP Fertilizer*. Retrieved from https://www.nbclindia.com/products/single-super-phosphate-ssp/single-super-phosphate-ssp

National Academy of Agriculture Sciences . (2019). ZBNF-A Myth or Reality . New Delhi.

Nutrition and You. (n.d.). *Chilli Peppers Nutrition Facts*. Retrieved from Nutrition and You: https://www.nutrition-and-you.com/chili-peppers.html

Ozkan B., A. H. (2004). *Energy requirementand economic analysis of citrus production in Turkey.*

Pelletier, N., Audsley, E., Brodt, S., Garnett, T., Henriksson, P., Kendall, A., et al. (n.d.). *Energy Intensity of Agriculture and Food Systems.*

Pervanchon F., B. C. (2002). *Assessment of energy use in arable farming systems by means of an agro-ecological indicator: the energy indicator.*

Pishgar-Komleh, S., Sefeedpari, P., & Rafiee, S. (2011). Energy and Economic Analysis of RIce Production under Different Farm Levels in Guilan province in Iran. *Energy*.

Seyyedhassan Pishgar-Komleh, P. S. (n.d.). *Energy and economic analysis of rice production.* 2011.

Zoghipour A., T. J. (2011). *Analysis data energy input-output in the agricultural section of Iran.*