Assessment of Cultivation Method for Energy Beet Based on LCA Method

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Abstract In order to establish a supply system for energy resource coupled with the environment, the production technology of sugar beets was explored as a biological energy source. The low-humic andosol as the experimental soil, the panting method was direct planting, and cultivation technique was minimum tillage direct planting method. The control was conventional tillage transplant and no tillage direct planting. The results demonstrated that data revealed that the energy cost of no tillage and a direct planting method was 105 GJ/hm^2 on average for two years, while that of the conventional tillage method was 112 GJ/hm^2 per year. The ratio of output to input showed that the direct planting with no tillage was more efficient (3.61) than the conventional tillage (3.01). Moreover, the emission of CO_2 into the atmosphere with no tillage and the direct planting was 71% of the conventional tillage planting technique. Therefore, direct planting without tillage reduces the impact on the environment.

Key words Beet, Cultivation methods, LCA (Life Cycle Assessment)

Organism is of regenerative properties and carbon cycle balance nature and the biological resources provide the conditions for environmental coordination-based energy raw materials. The effective use of bio-energy has become an international trend[1]. To achieve environmental coordination-based society, it is necessary to establish the supply system of biological raw material, that is, a large area of production or planting of energy crops is required[2].

Currently, the fossil fuels are gradually depleted, and the greenhouse effect and other natural disasters occur frequently. The development of bio-energy with regenerative capacity is a top priority. Beet is one of the main crops in the dry farming in Hokkaido, Japan, and it occupies an important position in the rotation of crops. The annual cultivation area of beet accounts for about the annual cultivation area of 25% of total dry crops (about 68000 hm^2), and the annual sugar production is 0.8 million t[3]. To ensure the growing area of beet and learn the planting experience from the U.S. and Brazil[2], it is necessary to take the currently planted beet as ethanol to extract raw material for production.

As an energy crop, beet is one of crops containing high energy in the crops planted in Hokkaido, Japan[3]. It is concentrated for collection and has advantage of transportation costs easy to be reduced when compared to the unused residue resources. Meanwhile, the trait of raw materials is stable, conducive to the extraction of ethanol. What can be used in the beet is not merely the roots. The studies of Ogata *et al.*[4] show that the beet stems and leaves contain high energy, and are also raw materials for ethanol extraction. If planting beet as the raw material for the extraction of ethanol and other biofuels, Hokkaido can be converted into the supply base of bio-energy.

In order to overcome these shortcomings, the basic plan of Japanese food, agriculture, and rural areas points out that it is necessary to strengthen the direct seeding technique of beet, reduce the labor time by 20%, and increase the yield by 10%. To achieve this target, the soil and suppression conditions suitable for direct seeding are analyzed. The surface soil with the particle size of below 20 mm accounts for more than 80% of pale volcanic ash soil[5] (occupying 37% of dry farming soil in Hokkaido), and if it is pressed down appropriately, the direct beet seedling emergence will be significantly increased[6].

Through the survey, the link with large field energy input to crop production is generally the soil movement operation, such as plowing and soil preparation[7]. To create an energy-saving cultivation system, an effective way is to simplify or totally omit the part of the above mechanical operation. Light-colored volcanic ash soil is of good drainage and softness nature, and many other characteristics, and there is possibility of simplification or even omission in terms of farming and soil preparation[7].

Up to now, there are few experiments studying the beet to be planted as the raw material for ethanol. This study simplifies the ploughing and land preparation operation as far as possible, and combines it with the direct seeding cultivation method, to explore the energy-saving cultivation technique and production capacity of beet as the energy crop.

Meanwhile, this article compares it with the current transplant cultivation method in terms of growth period and yield characteristics of beet. According to LCA (Life Cycle Assessment) method, this article also analyzes the energy balance in the cultivation process, and the possibility of beet as the energy crop to be cultivated, and assesses the environmental impact.

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1 Materials and methods

1.1 Energy-saving cultivation of beet

1.1.1 Soil for experiment and experimental treatment. The field experiment in this study was carried out in Dry Farming Department, Center for Agricultural Research in Hokkaido, Japan. The site for experiment is located in central Tokachi plain (a region with typical agricultural dry land in Japan), and the temperature is similar to that of northern China.

The experimental period is two years (2009 – 2010), and the soil for experiment is pale volcanic soil. The experimental treatments are shown in Table 1. According to the experiment, the cultivation methods can be divided into direct seeding method and transplant method (hereinafter referred to as tillage transplant plot). According to the land preparation method, in the direct seeding, it is divided into simple tillage plot I (hereinafter referred to as simple tillage direct seeding plot I), plotII(hereinafter referred to as simple tillage direct seeding plot II), and non-tillage plot (hereinafter referred to as non-tillage direct seeding plot.

Table 1 Composition of the experimental plot

Name of the experimental plot	Planting methods	Land preparation methods
Simple tillage direct seeding plot I	Direct seeding method	Deep scarification 30 cm
Simple tillage direct seeding plot II	Direct seeding method	Deep scarification 30 cm + rotary tillage 10 cm
Non-tillage direct seeding plot	Direct seeding method	0
Tillage transplant plot	Transplant method	Deep scarification 30 cm + rotary tillage 20 cm

The land preparation machinery for simple tillage direct seeding plot I is subsoiler, with the tillage depth of 30 cm; the land preparation machinery for simple tillage direct seeding plot II includes subsoiler and rotary tiller, with the tillage depth of 30 cm and 10 cm, respectively; there is not any land preparation operation before sowing for the non-tillage direct seeding plot. The tillage transplant plot refers to the conventional cultivation system of Hokkaido as a reference[9], that is, the tillage depth of subsoiler is 30 cm, and the tillage depth of rotary tiller is 20 cm.

However, due to the fine particle size of topsoil of the pale volcanic ash soil, the rotary tillage is barely carried out after the deep scarification locally, and there is usually only one land preparation operation.

According to the survey results of growth period and yield in 2009, there were no significant differences between simple tillage direct seeding plot I and simple tillage direct seeding plot II. In 2010, the field experiment was only carried out in the simple tillage direct seeding plot II, and the treatment for simple tillage direct seeding plot I was omitted.

In 2009, the fore-rotating crop in the experimental plot was wheat, and the plot was ploughed up after harvest; the ground surface was levelled. In 2010, the fore-rotating crop in the experimental plot was unplanted, and the treatment was the same as that of previous year. The area of field for experiment was 2000 m^2, 8 ridges in each plot, and the planting density is the same; 80000 plants were set in 1 hm^2 of plot, with the planting distance of 21.5 cm and ridge distance of 60 cm. There were 4 treatments in the experiment plot in 2009 and there were 3 treatments in the experiment plot in 2010. The experiment plot was repeated three times in the two years, and it is arranged in a random manner.

1.1.2 Farming summary. The seed for the experiment was "Beihai 87" coated seed which was a variety likely to be popularized for the local direct seeding. The fertilizer for the experiment was special fertilizer for beet, and the name of fertilizer was S. 014. The application rate of fertilizer was 1000 kg/hm^2, and the sowing and fertilization were carried out at the same time.

The seeding period in the direct seeding plot was April 19, 2009 and May 2, 2010; the seeding-machine for the experiment was the vacuum extraction seeding-machine (Tabata TEB – 4WR), which completed the ditching, fertilizing, planting and repression at the same time.

The transplant period of tillage transplant plot was April 25, 2009 (39 days after sowing), and May 2, 2010 (36 days after sowing). The artificial transplant was adopted, and the land preparation operation was carried out in the three days before planting.

After seeding or transplanting, the field management was carried out in accordance with conventional methods. To control weeds before planting in the direct seeding plot, the soil chemical treatment was carried out in 2010, and the direct seeding plot completely omitted the intertillage weeding operation in the two years.

1.1.3 Survey items and survey methods. The survey items during the growth period of beet include germination rate, plant height and leaf number.

The survey method for the germination rate survey is as follows:

The ratio of the actual number of seedling to the theoretical number of seedling in continuous 2 m was calculated, three points were surveyed in each experiment plot, and then the average was taken. After that, the position of germination, plant height, leaf number and yield were surveyed. The survey items in the harvest period include root weight, stem and leaf weight, and sugar content.

The survey method for sugar content is as follows: 15 consecutive plants in the survey position were chosen for determination, and the analysis device was the automatic analysis device for sugar content (Venem, Sugar Beet Analyzing System). To study the relationship between the individual weight and sugar content, the sugar content of roots, stems and leaves of individual sample was determined, and the instrument for experiment is BRIX sugar meter (IATC – 1E handheld sugar polarimeter). Meanwhile, the beet roots in the direct seeding plot were graded for survey.

1.2 Energy balance and CO_2 emission Based on the differences in the operation system, we carry out analysis of direct and indirect energy input as well as the direct and indirect CO_2 emission, according to 1 hm^2 of area.

The object of analysis includes field operation, transportation of means of production, and transportation of harvested product, but the input to the extraction of ethanol in the plant is not within the scope of this analysis.

The analysis and calculation results of fuel energy conversion coefficient and CO_2 emission conversion coefficient can be shown in Table 2.

Table 2 Calculation of fuel energy conversion coefficient and CO_2 emission conversion coefficient

Classification		Energy input [A]		CO_2 emission [B]	
		Conversion coefficient a	Unit	Conversion coefficient b	Unit
Direct input	Diesel fuel	38.5	MJ//L	2.619	kg//L
	Gasoline	35.2	MJ//L	2.322	kg//L
	Ethanol	23.4	MJ//L		
	Kerosene	37.3	MJ//L	2.489	kg/L
	Electricity	3.6	MJ//kWh	0.378	kg/kWh
Indirect input	Agricultural machinery	48.558	kJ//yen	3.743	g//yen
	Pesticide	47.608	kJ//yen	3.119	g//yen
	Chemical fertilizer	77.777	kJ//yen	5.253	g//yen

Note: The conversion coefficient a for energy input and conversion coefficient b for CO_2 emission in the table are from Handbook of Biological Resources[8] compiled by Energy Society of Japan, and the "Input-output Table"[9], respectively.

1.2.1 Direct energy input and CO_2 emission. The direct energy input includes the conversion value of energy of electricity and fuel needed by the greenhouse nursery operation and field operation.

According to the operating system of various experimental treatments, we calculate the fuel consumption required for 1 hm^2 based on formula (1).

$$Q_{b1} = V \times \varphi \quad (1)$$

where Q_{b1} is the direct input energy (MJ/hm^2); V is the fuel consumption in the mechanical operation (L/hm^2); φ is the conversion coefficient (MJ/L) (Table 2 [A]).

The operating system of various treatments is shown in Table 3, and it is the same case for the experimental machinery. As for the application of herbicides and fungicides, the soil treatment is carried out after sowing only in the direct seeding plot; for other experiment plots, the spraying amount and frequency are the same.

For the transport of production materials, the distance between the farmers and cultivation site is assumed to be 3 km, and the loading amount of truck is assumed to be 4 t. According to the frequency of transport needed by each treatment, the fuel consumption is calculated. For the transport of harvested product, the distance between the cultivation site and the ethanol extraction plant is assumed to be 10 km, and the loading amount of the truck is assumed to be 10 t. The fuel consumption is calculated using the same method.

The electricity used for the greenhouse seedling cultivation in the tillage transplant plot is calculated by Koga *et al*.[10] at 49.5 kWh/hm^2. The consumption of kerosene for heating in the greenhouse is also calculated. Through the survey, we can find that the greenhouse area required for per hectare of transplanted seedlings is 29.7 m^2. The nursery generally needs 3 weeks from 10 March. According to the energy consumption of 50000 kcal/h, when the minimum temperature of the greenhouse is assumed to be 5℃, the amount of kerosene consumed is 37 L/hm^2[11].

Table 3 Each operating system's operation name

Operation name	Machine name	A	B	C	D
Deicing salt spread	Deicing salt spreaders	○	○	○	○
Nursery (within greenhouse)	Small planter, heating	●	●	●	○
Soil conditioner spread	Powder spreaders	○	○	○	○
Soil treatment agent spread (weeding)	Pesticide spreaders	○	○	○	●
Deep scarification	Subsoiler	○	○	●	○
Soil crushing, land preparation	Rotary tiller	●	○	●	○
Fertilizing, seeding	Integrated fertilizer seeder	○	○	○	○
Lifting, transportation	Truck (4 t)	●	●	●	○
Transplant	Beet transplanter	●	●	●	○
Herbicides spread (3 times)	Pesticide spreaders	○	○	○	○
Cultivation	Cultivators	●	●	●	○
Pest control (5 times)	Pesticide spreaders	○	○	○	○
Harvest	Beet harvester	○	○	○	○
Deep scarification	Subsoiler	●	●	●	○
Compost	Compost spreaders	○	○	○	○
Autumn plowing	Five – furrow plough	○	○	○	○
Transportation of means of production	Truck (4 t)	○	○	○	○
Transportation of harvest	Truck (10 t)	○	○	○	○

Note: A-simple tillage direct seeding plot I; B-simple tillage direct seeding plot II; C – non-tillage direct seeding plot; D-tillage transplant plot; ○-operation; ● – no operation.

The CO_2 emission in the cultivation site is calculated with the field operation machinery as the emission target of CO_2. Based on the type of fuel input, the coefficient in Table 2[B] is used, and it is calculated according to formula (2).

$$C_{b1} = V \times \tau \quad (2)$$

where C_{b1} is the direct CO_2 emission (kg/hm^2); V is the fuel consumption in machinery operation (L/hm^2); τ is the CO_2 direct emission coefficient (kg/L) (Table 2[B]).

1.2.2 Indirect energy input and CO_2 emission. Indirect input refers to the energy consumed in the manufacture of agricultural machinery, pesticides and chemical fertilizers for each cultivation system. Meanwhile, along with the energy consumption, the CO_2 is emitted. The calculation of the indirect energy input and CO_2 emission requires enormous computing data, so it is very complex.

Therefore, out operation is based on the Industry Association Table of National Institute for Environmental Studies[12], and it is calculated in accordance with the local sale prices of agricultural machinery, pesticides and chemical fertilizers.

The energy consumed for the transport of agricultural machinery from the manufacturing plant to the cultivation site, and the CO_2 emission, are not calculated in this paper. The indirect energy input and CO_2 emission are calculated based on formula (3) and (4), respectively.

$$Q_{b2} = R \times \varepsilon \quad (3)$$

$$Q_{b2} = R \times \delta \quad (4)$$

In formula (3), Q_{b2} is the indirect energy input (MJ/hm^2); R is the sale price (farm machinery, pesticides, and chemical fertilizers) (yen/hm^2); ε is the energy conversion coefficient (MJ/yen) (Table 2 [A]). In formula (4), C_{b2} is the indirect emission of CO_2 (kg/hm^2); R is the sale price (farm machinery, pesticides, and chemical fertilizers) (yen/hm^2); δ is the unit coefficient of CO_2 emission (kg/yen) (Table 2 [B]).

In this study, the sales price of agricultural machinery uses the sales price provided by Hokkaido Industry Federation[13]. Meanwhile, the service life of agricultural machinery prescribed by the industry[14] is used to calculated the annual input costs.

In the cultivation system, except beet transplant machine and beet harvester, beet and other cultivated crops share the machinery. According to the local rotation system, it is derived by quartering the indirect energy input of agricultural machinery and indirect emission of CO_2. The sales prices of chemical fertilizers and pesticides refer to the sales prices of Hokkaido Agricultural Society as a reference[15].

1.2.3 Energy balance and total CO_2 emission. The beet energy is converted into the ethanol conversion amount by the sugar harvest, and the energy output is calculated according to formula (5). Formula (6) is the energy balance, and input-output ratio is calculated according to formula (7). 0.55 in formula (5) is the measured coefficient of ethanol converted from beet[16-17].

$$Q_a = S \times 0.55 \times 23.4 \quad (5)$$

$$Q = Q_a - (Q_{b1} + Q_{b2}) \quad (6)$$

$$Q_c = Q_a / (Q_{b1} + Q_{b2}) \quad (7)$$

where Q_a is the total energy output (MJ/hm^2); S is the sugar equivalent amount (kg/hm^2); 0.55 is the efficiency of conversion of beet sugar into ethanol; 23.4 is the heat productivity of ethanol (MJ/L); Q is the energy balance (MJ/hm^2); Q_c is the input-output ratio of energy.

The total CO_2 emission is the sum of direct and indirect emission of CO_2. CO_2 absorbed for the crop photosynthesis is an important part of the carbon cycle, and it is considered that using the amount of CO_2 absorbed for the crop photosynthesis and total CO_2 emission to calculate the carbon cycle is not proper.

The studies of Koga *et al.*[10] show that the farmland carbon cycle and the soil surface carbon balance are significantly correlated with the depth of tillage and the residue treatment after harvest. According to the existing conditions, we do not take the CO_2 balance as the calculation object, but only calculate the total CO_2 emission of different cultivation systems.

2 Results and analysis

2.1 The impact of various cultivation systems on emergence, growth and harvest Sowing depth and germination rate are shown in Table 4. The upper part of the table is the data in 2009 and the lower part of the table is 2010 data. The soil crushing performance of topsoil is good, resulting in consistent sowing depth, and the germination rate in various plots is above 80%.

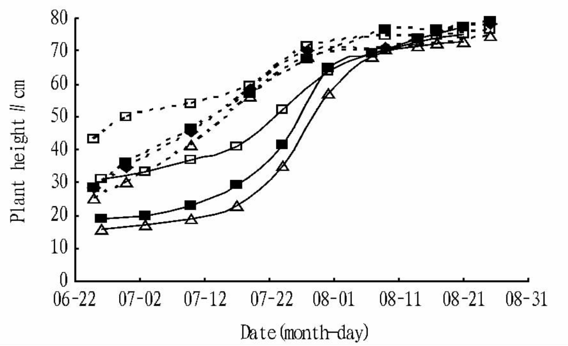
There are not significant differences in the germination rate between the treatments. However, the germination period in simple tillage direct seeding plot I is slightly longer than the germination period in other experiment plots, and the seedlings are irregular, so the treatment in 2010 is omitted.

Table 4 Sowing depth and germination rate survey

Name of the experimental plot	Sowing depth //cm	S. D. //cm	Germination rate //%	Correlation
Simple tillage direct seeding plot I	1.8	0.45	81.5	n. s
Simple tillage direct seeding plot II	1.9	0.35	90.0	n. s
Non-tillage direct seeding plot	2.1	0.40	86.0	n. s
Simple tillage direct seeding plot II	1.3	0.81	85.7	n. s
Non-tillage direct seeding plot	2.1	0.63	90.5	n. s

Note: S. D. is the standard deviation; n. s means the difference is not significant.

The plant height is shown in Fig. 1, and the direct seeding plot gradually catches up with transplant plot after the mid-July. In terms of the tillage method, it is poorer in non-tillage direct seeding plot than in simple tillage plot, but in early August, it basically reaches the same level. Over the time, the leaf number also shows the same tendency. The two years of experimental results show that compared with the beet transplant cultivation, the growth is rapid under direct seeding cultivation.



Note: The dotted line is 2009 and solid line is 2010; △ is non-tillage direct seeding plot; ◆ is simple tillage direct seeding plot I; ■ is simple tillage direct seeding plot II; □ is tillage transplant plot; the same hereinafter.

Fig. 1 The plant height over the time

The survey results of dry matter harvest, sugar content and sugar amount are shown in Table 5. The differences between various treatments are not significant. In the Hokkaido Tokachi area, the root harvest yield is reduced by about 14% under beet direct seeding when compared with transplant. However, the survey of Hokkaido Beet Association in 2004 shows that there is only the difference of 10% in the harvest between excellent direct beet seeding cultivation technique and transplant[18].

This experiment was carried out in the pale volcanic ash soil with good soil physical properties. Compared with transplant plot, the root weight in direct seeding plot was reduced by 2.4% – 5.4% in 2009; the root weight in direct seeding plot was reduced by 4.1% – 9.2% in 2010.

The main reason for the yield reduction lies in the phenomenon of continuous short of seedling in the direct beet seeding plot. There are no differences in the measurement results of sugar content between direct seeding plot and transplant plot. There are also no significant differences in the root weight and sugar content between the cultivation methods in the direct seeding plot.

These results prove that the non-tillage direct seeding method with less energy input can help us still obtain higher beet yield in the pale volcanic ash soil.

Moreover, this experiment recycles some stems and leaves plunging into the soil after the harvest, and utilizes them as raw materials for energy. Taking non-tillage direct seeding plot for example, the sugar amount of stems and leaves is 14 % – 16% of that of roots, and the sugar yield in stems and leaves per hectare is 1610 – 1740 kg.

The relationship between dry matter harvest of individual beet and sugar amount is shown in Fig. 2. In the figure, the straight line signifies beet roots and the line below signifies the stems and leaves of beet. As can be seen from the figure, there is a direct proportion relationship between the dry matter amount and individual beet amount, but there is almost no relationship between the dry matter amount and the cultivation methods as well as the land preparation method. It can also indicate that the dry matter amount of individual beet is correlated with the energy it contains.

Based on this relationship, as for the beet direct seeding, in order to prevent yield decrease caused by the shortage of seedlings, it can appropriately increase the sowing amount, and ensure the yield per unit area, to obtain the same yield as that under transplant.

In the future, it is necessary to take it as the basic research and clarify the relationship between the cultivation density and harvest.

Table 5 The survey results of dry matter harvest, sugar content and sugar amount

Name of the experimental plot	Dry matter harvest // kg/hm^2		Sugar content // %		Sugar amount // kg/hm^2	
	Roots	Stems and leaves	Roots	Stems and leaves	Roots	Stems and leaves
Simple tillage direct seeding plot I	16 690	6 260	18.7	3.7	13 020	1 780
Simple tillage direct seeding plot II	16 670	6 240	18.1	3.8	12 590	1 780
Non-tillage direct seeding plot	16 180	6 110	18.4	3.6	12 420	1 740
Tillage transplant plot	17 100	6 320	18.7	3.7	13 330	1 800
Simple tillage direct seeding plot II	16 910	6 900	16.6	3.7	11 660	1 960
Non-tillage direct seeding plot	16 020	5 670	15.3	3.6	10 240	1 610
Tillage transplant plot	17 630	5 080	17.3	3.7	12 770	1 450

Note: The upper part is the year 2009; the lower part is the year 2010.

When harvesting the beet in the non-tillage direct seeding plot, there is the phenomenon of lateral roots. The survey results (Table 6) show that "relatively large" and "large" account for 67%, but for the tillage transplant plot, it is only 26%. The tillering situation in simple tillage plot II is between the two.

Tillering roots can be easily absorbed by soil. However, it is likely to cause damage in treatment, resulting in the decay and low rate of finished products. With the production of beet as the raw material for ethanol, the tillering root evaluation is an indispensable subject in the future.

2.2 Energy gain and CO_2 emission

2.2.1 Direct energy input and direct CO_2 emission. The direct energy input in various cultivation systems is shown in Table 7.

In this experiment, the system with the largest direct seeding input is simple tillage direct seeding plot II, with the input of 6950 MJ/hm^2; the system with the smallest direct seeding input is non-tillage direct seeding plot, with the input of 5 710 MJ/hm^2.

The non-tillage direct seeding plot without carrying out land

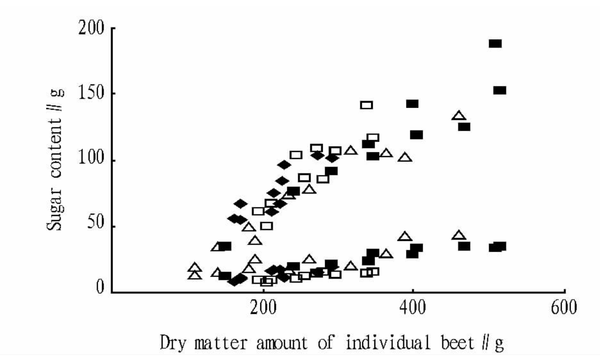


Fig. 2 The dry matter amount of individual beet and sugar amount in 2010

preparation operation has the maximum energy-saving effect, and it is reduced by 51% when compared with the energy input of tillage transplant plot.

Table 6 Survey results on lateral roots (2006) Unit: %

Tillering degree	Simple tillage direct seeding plot II	Non-tillage direct seeding plot	Tillage transplant plot
Small	60	33	73
Relatively large	27	27	13
Large	13	40	13

Note: The number of individuals surveyed is 30 in each plot.

The study also shows that compared with the transplant method, the minimum energy input under tillage direct seeding can be reduced by 40%. The lowest CO_2 emission is in non-tillage direct seeding plot (390 kg/hm^2), and the highest CO_2 emission is in transplant plot (800 kg/hm^2).

The direct CO_2 emission under non-tillage direct seeding method is reduced by 51% when compared with the tillage transplant method.

2.2.2 Indirect energy input and indirect CO_2 emission. In the manufacturing of agricultural machinery, pesticides and chemical fertilizers, the indirect energy input and indirect CO_2 emission are shown in Table 8. Among them, the energy input of pesticides is the most, and except tillage transplant plot, the energy input of agricultural machinery and chemical fertilizers are basically the same.

The analysis results of the experiment plot show that the energy required by the manufacture of agricultural machinery for simple tillage direct seeding plot I, simple tillage direct seeding plot II and non-tillage direct seeding plot, is less than 50% of the energy required by the manufacture of agricultural machinery for tillage transplant plot. The gap is mainly caused by land preparation machinery or transplant machinery.

In various systems, since the application rate of chemical fertilizers and pesticides is basically the same, there is a small difference in the energy input between the two. The indirect CO_2 emission also shows the same tendency. The gap between indirect energy input and indirect CO_2 emission, and direct input can reach as high as 4 – 6 times.

In this study, the service life of agricultural machinery uses the theoretically recommended service life, and the actual service life of agricultural machinery is longer than the theoretically recommended service life.

Therefore, in order to pursue the accuracy of the analysis, it is necessary to survey the actual service life of agricultural machinery.

Moreover, this article takes the crop of beet as an analysis object, and the agricultural machinery shared by all the crops in the rotation system divided by the rotation crop types is the part of agricultural machinery used for beet. In the future, it is necessary to carry out LCA evaluation of whole rotation system.

Table 7 Direct energy input and direct CO_2 emission

Name of the experimental plot	Diesel fuel L/hm^2	Diesel oil L/hm^2	Kerosene L/hm^2	Electricity kWh/hm^2	Direct energy input MJ/hm^2	CO_2 emission kg/hm^2
Simple tillage direct seeding plot I	157.7	1.8	0.0	0.0	6130	420
Simple tillage direct seeding plot II	178.8	1.8	0.0	0.0	6950	470
Non-tillage direct seeding plot	146.6	1.8	0.0	0.0	5710	390
Tillage transplant plot	260.6	1.8	36.7	49.5	11640	800

Table 8 Indirect energy input and indirect CO_2 emission

	Name of the experimental plot	Agricultural machinery	Pesticides	Fertilizers	Total
Input costs // yen/hm^2	Simple tillage direct seeding plot I	161 830	393 160	112 830	667 820
	Simple tillage direct seeding plot II	169 470	393 160	112 830	675 460
	Non-tillage direct seeding plot	149 100	393 160	112 830	655 090
	Tillage transplant plot	346 890	389 130	112 830	848 850
Energy input // MJ/hm^2	Simple tillage direct seeding plot I	7 860	18 720	8 780	35 360
	Simple tillage direct seeding plot II	8 220	18 720	8 780	35 720
	non-tillage direct seeding plot	7 240	18 720	8 780	34 740
	Tillage transplant plot	16 840	18 520	8 780	44 140
CO_2 emission // kg/hm^2	simple tillage direct seeding plot I	610	1230	590	2 430
	simple tillage direct seeding plot II	630	1230	590	2 450
	non-tillage direct seeding plot	560	1 230	590	2 380
	Tillage transplant plot	1 300	1 210	590	3 100

2.2.3 Energy balance and total CO_2 emission. The average conversion amount and energy output of ethanol in the two years are shown in Table 9. The amount of ethanol is converted from the beet sugar, so it is the highest in the tillage transplant plot, reaching 7180 L per hectare, and the converted energy reaches 167900 MJ/hm^2.

Compared with tillage transplant plot, the yield of non-tillage direct seeding plot with the lowest harvest is reduced by 13%, reaching 6230 L per hectare. The studies of Ogata *et al.*[18] show that relying on various devices and techniques, the conversion rate can be improved.

We analyze some stems and leaves abandoned in the previous beet harvest. Taking non-tillage direct seeding plot for example, the conversion amount of ethanol reaches 930 L/hm^2, and the energy output in this part is expected to increase to 21650 MJ/hm^2.

Table 9 Theoretical yield of ethanol and energy

Name of the experimental plot	Ethanol harvest//L/hm^2		Energy//MJ/hm^2	
	Roots	Stems and leaves	Roots	Stems and leaves
Simple tillage direct seeding plot I	7 160	980	167 540	22 930
Simple tillage direct seeding plot II	6 670	1 030	155 960	24 100
Non-tillage direct seeding plot	6 230	930	145 780	21 650
Tillage transplant plot	7 180	900	167 900	20 940

Note: The values in the table are the average values in two years; the same hereinafter.

The average energy balance and total CO_2 emission in two years are shown in Table 10. Energy gain is the difference between energy output and energy input. Experimental results show that it is the highest in simple tillage direct seeding plot I. For the tillage transplant plot, the energy output is high, but the energy input is also high, and the offset between the two makes its energy gain lower than that of simple tillage direct seeding plot.

For the non-tillage direct seeding plot, the low harvest makes the energy gain low. The productivity indicator is the ratio of output to input. The productivity of the study in direct seeding is higher than in transplant, with the range of 3.61 - 4.01.

Total CO_2 emission is the lowest in the non-tillage direct seeding plot (2770 kg/hm^2), lower than that in tillage transplant plot (3900 kg/hm^2), which fully proves this mode of production reduces the environmental impact.

Table 10 The energy balance and total CO_2 emission of roots

Name of the experimental plot	Net energy income//MJ/hm^2	Output/input	The total CO_2 emission//kg/hm^2
Simple tillage direct seeding plot I	126 050	4.04	2 850
Simple tillage direct seeding plot II	113 350	3.66	2 920
Non-tillage direct seeding plot	105 360	3.61	2 770
Tillage transplant plot	112 200	3.01	3 900

3 Conclusions

Beet is regarded as the raw material for bio-energy, and we explore the energy-saving cultivation technique. Through two years of research, we identify the following results:

(i) It is likely to generate lateral roots in the non-tillage direct seeding plot when compared with the simple tillage direct seeding plot, but there are not significant differences in the germination, growth period and yield. The root harvest in the non-tillage direct seeding plot is reduced by 2.5% - 9.2% when compared with the existing tillage transplant plot. (ii) Through the LCA method, in terms of the energy gain, the input-output ratio of non-tillage direct seeding plot is 3.61 - 4.04, higher than that of tillage transplant plot. The two - year analysis results show that the energy gain of non-tillage direct seeding plot is 105 GJ/hm^2, and its total CO_2 emission is 71% of that of tillage transplant plot, reducing the impact on the environment.

4 Discussions

Beet is one of the major dry land crops in Hokkaido. It is widely grown in Northeast China, North China, northwestern inland or frontier provinces, and it occupies an important position in the relationship between the sugar industry and the growers. The studies of Venturi *et al.*[19] show that when the direct seeding beet is used as energy, the ratio of output to input is 2.8 - 3.2. The gap is mainly caused by the difference in the sugar beet production between regions.

In this study, the productivity of non-tillage direct seeding plot is higher than that of tillage transplant plot. As described in this study, the development of stable production technology that can avoid the lateral roots will be an important subject. As Japan's domestic consumers voice desire to change the sugar prices in order to be in line with the international standards, the price of sugar will be bound to decline, according to the waning sugar demand in Japan.

To maintain the normal crop rotation system and ensure sustainable land use, it is necessary to guarantee the beet cultivation area in the production. So, in Hokkaido, Japan, it is necessary to grow beet as the raw material for bio-energy at low cost, study and evaluate its cultivation techniques.

We explore the low-cost cultivation technique of beet as the raw material for bio-energy, and analyze the energy gain of various

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ea, we selected sugarcane areas of Nanning Sugar Industry Company and compared the actual yield data in 2010/2011 season with out prediction value, and found that the prediction accuracy is up to 90.2%. This indicates that our prediction model for climatic yield can reach the prediction accuracy above 90%.

4 Conclusions

The prediction model of climatic yield of sugarcane is based on superposition and analysis of spatial distribution of climatic disasters and distribution of sugarcane planting areas. For the sugarcane yield of a certain year, it is feasible to make prediction according to current climatic prediction data provided by the meteorological authority and sugarcane growth vigor. Therefore, it is recommended to properly arrange grinding season according to distribution of rainfall in the same year, to facilitate increasing sugar content in the grinding season. Besides, it should make proper arrangement of sugarcane harvesting and transport works. For areas vulnerable to frost disasters annually, it is proposed to give priority to harvesting and transport, so as to reduce losses due to frost disasters. Finally, sugarcane farmers should make proper adjustment of sugarcane harvesting, transport and grinding season according to actual growth of sugarcane and prediction results of the yield.

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cultivation systems. At the same time, using LCA method, we evaluate the impact of various cultivation systems on environment. The results show that in terms of input-output ratio, the direct seeding cultivation of beet is superior to transplant cultivation, and the load of direct seeding cultivation on environment tends to decline.

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