Measure and comparison of economic, social and ecological sustainability of farming systems in the Marvdasht plain

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Abstract

Agricultural sustainability refers to the ability of a cropping system to produce, without causing irreversible damage to the ecosystem. There is an increasing need to view cropping systems and identify management practices in a holistic indicator-based impact assessment. The main objective of this study was to compare and rank the cropping systems of the Marvdasht plain in Fars Province; in order to show the gap between them. To achieve this aim, sustainability were divided into four levels based on Composite Index(CI),which is useful for the identification of sustainability and includes three dimension: (1) economical, (2) social, and (3) environmental and consist of 11 indicators. Required data were collected by questionnaire from 200 cropping farmers who were selected through a stratified sampling design from six regions located in Marvdasht plain. The computer software of SPSS was used to analyse the data. Indicators were normalized using the division by means technique and were weighted. The weightings were derived from Principal Component Analysis (PCA). CI was used to map the sustainability levels at the plain. According to classifying CI, four categories were identified, which zone 6 identified as being unsustainable, while two zones 2 and 3 were considered as belonging to the relatively unsustainable and the zone 5 was identified as relatively sustainable and the remaining zones (1,4) were classified as sustainable. We conclude that the usage of multidimensional and holistic CI for analysing sustainability of complex cropping systems is extremely important.

Keywords: Composite index; Cropping system; Ecological sustainability; Economic sustainability; Social sustainability

1. Introduction

Agriculture contributes 24% of global GDP and provides employment to 1.3 billion people or 22% of the world's population (Smith *et al*., 2007). It is a critical sector of the world economy. Agriculture is one of the most important economic sectors in Iran, and comprises a considerably high percentage of production and employment.

About 25% of Iran Gross National Product (GNP), 33% of employment, 25% of non-oil exports, and 80% of food requirements have been provided by the agricultural sector (Karbasioun et al., 2008). Nevertheless, there are various evidence that agriculture still lags far behind its real potential, considering the country's available resources (Karami and Rezaei-Moghaddam, 1998). In addition, sustainable land use has not yet been achieved. For instance, about 30% of the forests located in the north of Iran were destroyed during the last two decades. Furthermore, large portions of pastures and grasslands were rendered unproductive because of overuse by the cattle of the nomadic communities and farmers (Darvishi, 2003). Agricultural Development policy in Iran, which has been based on modernization approach in the past decades, has brought about negative impacts such as uneven development, poverty and environmental degradation (Rezaei-Moghaddam *et al*., 2005).

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As the ways in which cropping systems are managed and evaluated are heavily dependent on human values, economic and social components of cropping systems have been overemphasized in the past. There is an increasing need to view cropping systems and holistically identify remedial management practices (Pacini *et al*., 2004). Since the publication of the Brundtland report, the concept of sustainability has received increasing attention in agricultural research. There would appear to be some consensus that sustainability has three basic features: environmental soundness, economic viability and social acceptability (Dumanski and Pieri, 2000; Ogaji, 2005). Pannell and Schilizzi (1999) argue that sustainability indicators are practical and reasonable vehicle for attempting to deal with the multifaceted nature of the ambiguous term 'sustainability'. As understanding of the complex relationship between agriculture and environment increases, many indicators of agricultural sustainability, environmental sustainability and the effect of agriculture on natural resources and the environment have been developed (Wei *et al*., 2007). However, links between sustainability indicators and agricultural management practices on one hand, and economic policies on another hand, are not well defined. As a consequence, farmers, policy makers and administrators do not have enough information to alter management systems according to environmental needs (Ahuja, 2003).

Most of the survey on agriculture has been done by economists and is based on farm-level data. Economic studies have focused on the efficiency of resource allocation and development pattern differences between small and large farms while ignoring the sustainability. According to the sustainability paradigm, no single dimension should be allowed to dominate development decision. In fact, each of the spheres should be taken into equal consideration prior to any economic decision.

There are few studies on sustainability based on an indicators framework. One good example of the application of indicators in sustainability is an index system of sustainable development constructed by Xu (2004), which included five supporting systems consisting of 95 factors that are selected as basic indices at the provincial level. The few studies restricted to some parts of Iran, are marred by limitations of the methods, variables and indicators used, and are limited mainly to the identification of sustainability. There are new systems of agricultural sustainability indicators that stretch beyond the discrete measurement of environmental and economic conditions. Emphasis on social sustainability is influencing the makeup of current sustainability indicators (Meadows, 1994). Thus, good measurements of ecological and economic conditions remain very important to gauging progress toward sustainability. However, other indicators, especially social indicators, are playing a role in determining sustainability in general and agricultural sustainability in particular (Roseland, 1998). Thus, sustainable agricultural development includes three inter connected, mutually inclusive themes, or spheres: the ecology, society and economics (Fig. 1).
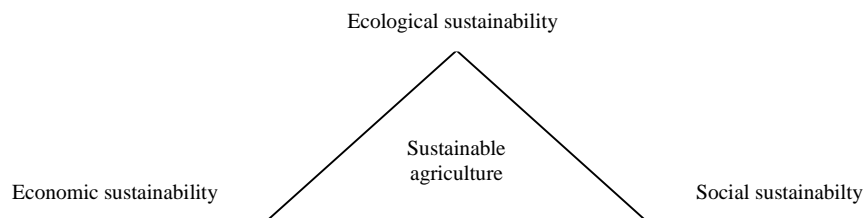

Fig. 1. The three dimension of sustainable agriculture

The parameters of sustainable agriculture have grown from an original focus on ecological aspects to include: first economic and then broader social dimension. The core concerns of sustainable agriculture are to reduce negative environmental and health externalities, to enhance and utilize local ecosystem resources, and preserve biodiversity. More recent concerns include topography, slope, and soil quality; in broader recognition for ecological sustainability in agricultural activities (Saltier *et al*., 1994; Hayati, 1995; Rezaie-Moghadam, 1997; Ingels *et al*., 1997; Comer *et al*., 1999; Boshard, 2000; Anderson, 2005). According to sustainable

paradigm, mechanization, fertilizer consumption, alternation cultivation, pesticides consumption, and irrigation cycle are the main indications of sustainable agriculture (Gahinl, 1998).

Economic perspectives on sustainable agriculture attempt to assign value to ecological parameters and include area under cultivation, agricultural productivity, and income earned from agriculture (Karami, 1995; Herzog and Gotsch, 1998; Pannell *et al.*, 2000; Comer *et al.*, 1999; Lyson, 1998; Glenn, 2000; Andreoli and Tellarini, 2000; Koeijer *et al.*, 2002; Rasul and Thapa, 2003; Gafsi *et al.*, 2006; Passel *et al.*, 2006).

In social aspect, sustainable agriculture is often associated with farmers' participation, their satisfaction, technical knowledge, ability of farmers and their social capital. (Guy and Rogers, 1999)

This paper is concerned with the identification and interpretation of sustainability dimensions. The purpose of this paper is to provide an analysis tool for improving the sustainability of cropping systems, in which a holistic impact assessment system is adopted. The intensively cropped systems of the Marvdasht plain is taken as the case study area. As a main agricultural production centre in Iran, the Marvdasht plain has different agricultural1attributes/characteristic in various proportions. Agricultural production in this plain includes a variety of activities and the obtained diverse results make it much more difficult to evaluate their sustainability.

In this research, an approach to construct composite index (CI) was first developed. Then the main results of sustainability disparities based on the collected data were analyzed. This allows a clearer comparison of sustainability levels. High or low levels of each characteristic (sub-indicator) were identified, sustainability levels c mapped, and possible strategies, which can be used to reduce the imbalances proposed. This new information can contribute to development planning, policy making and implementation.

2. Materials and Methods

2.1. The study area

Marvdasht plain is in the centre of Fars Province, with an area of 3687 km^2. It is the largest agricultural zone (containing 14% of the cultivated land) in the Fars Province. Irrigation is applied intensively and extensively, and agricultural water use accounts for approximately 94% of total water consumption in this region. In addition to water, farmers in the region use fertilizers intensively in order to maximize crop yields. However, there is evidence that farmers in this area over-fertilize and over-irrigate their crops (Shahvali, 2008; Mohammadi, 2009).

2.2. Methodology

The statistical population of this study consisted of wheat cropping farmers. Sample size included 200 persons selected through stratified random sampling. A questionnaire, including closed questions, was prepared and used for data collection. To pilot test the survey questionnaire, 30 interviews were carried out with selected farmers and some questions were changed, added, or deleted where necessary. A total of 200 questionnaires were completed and various quantitative methods of data analysis were applied. Descriptive statistical analyses, such as frequency tables, percentage, and mean were used to determine the general status of the studied society. Furthermore, composite index (CI) was used to evaluate of agricultural sustainability. The computer software of SPSS was used for data analysis.

$$n = \frac{N(t.s)^2}{Nd^2 + (t.s)^2}$$

(1)

$$n = \frac{35000(1.96 * 0.36)^2}{35000(0.05)^2 + (1.96.0.36)^2} = 200$$

The procedure for calculating CI is divided into two main parts. The first part is selection of proper sustainability indicators that belong to each sub-index and then computing the sub-index. The second is deriving the weights of sub-indices and combining these weights with the sub-indices to obtain the final CI. Providing an explicit conceptual framework for the CI before the selection of indicators, and the usefulness of multivariate analysis (PCA); to weight the individual indicators, allow for reduction of the number of individual indicators by aggregating them into a Composite Index (CI), which will enable comparisons of counties in specific dimensions regarding sustainability performance. Hierarchically, nine steps were followed in this research, which are summarized in Figure 2.

2.2.1. Selection of Indicators

Good indicators provide key information on environmental, social or economic system and they allow analysis of trends and cause and effect of relationships (Veleva and Ellenbecker, 2000).

Indicators should be separated from disparity-oriented indicators. Because of the limitations to related data, 11 indicators in three dimensions based on the conceptual framework were selected for the study.
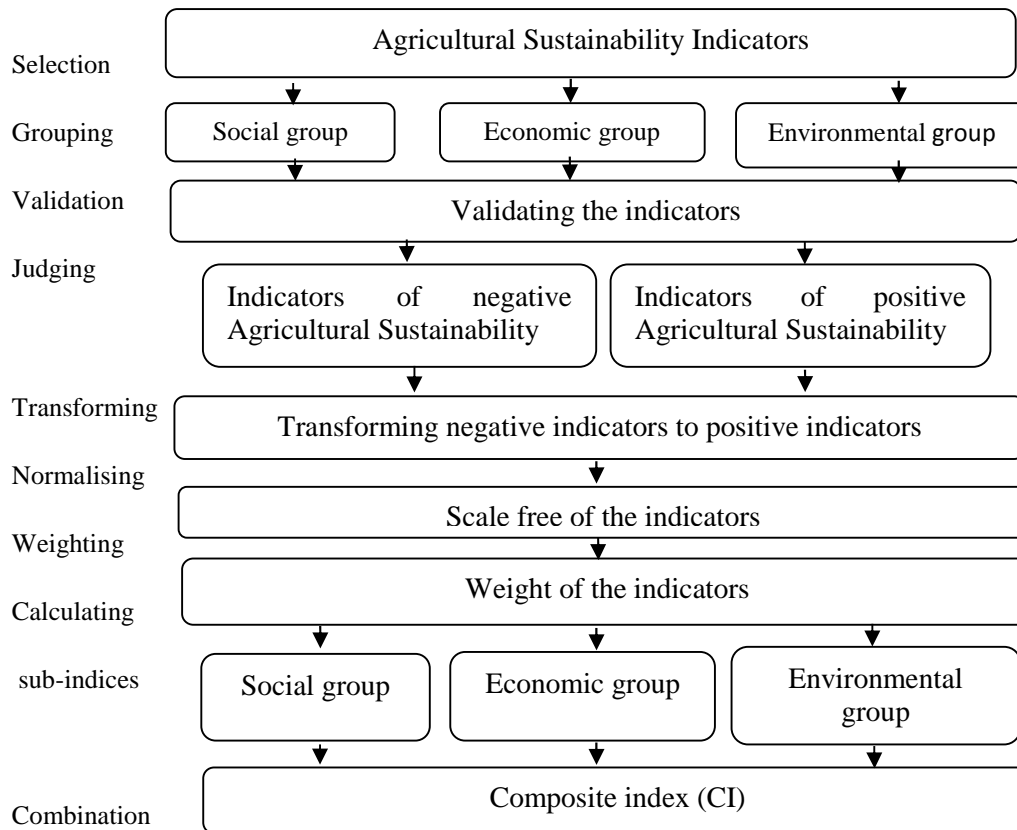

Fig. 2. Methodology of evaluation of Agricultural Sustainability (Source: Adopted from Krajnc and Glavic, 2005)

2.2.2. Grouping of Selected Indicators

Selection of indicators are fulfilled in grouping framework. The main dimensions of sustainabilty includes: Social, d=1, Economical, d=2 and Environmental, d=3 groups of indicators (Fig. 2).

2.2.3. Validation of the Indicators

According to Girardin *et al.* (1999) the methodology underlying the elaboration and development of indicators should fit scientific standards, which implies a procedure of validation. At this stage, the relevance and applicability of the indicators to the main research

goal, have been investigated by agricultural science experts and informants selected from academic members of Iranian faculties of agriculture who judged the validity of indicators based on mentioned objectives.

2.2.4. Judging the Indicators

Indicators have positive and negative impact on sustainability; so for aviodance of bias in the final result, positive and negative indicators should be discriminated. These two types of indicators are also denoted at this stage.

2.2.5. Transforming the Indicators

In this section, indicators that have negative impact on sustainability were converted to positive indicators. There are two methods for changing negative indicators to positive ones; converting the value of the indicators and subtracting from the absolute value (Kalantari, 2001). We employed the first method by using the following formula:

$$[Xij] = \frac{1}{Yij} \tag{2}$$

Xij is the indicators with positive value, Yij is value of the negative indicator j for county i.

2.2.6. Normalizing the Indicators

As each index uses different measurement scales, an elimination of scale bias was made. There are many methods for making the indicators scale-free. These include: ranking, standardized score, re-scaling, distance to a reference, categorical scales, indicators above or below the mean and division by mean (Nardo *et al.*, 2005). The method of dividing by mean was used to remove the scale biases. As Kalantari (2001) pertinently remarks, "If the observation for each indicator is

divided by the mean, one can get rid of the bias of scale without affecting the relative position of the region in the series. The transformation does not disturb the "dispersion" of the variables, since the coefficient of variation of the original series is retained as the standard deviation or the coefficient of variation of the transformed series." We adopted the division by mean as follows:

$$Zij = \frac{Xij}{X} \tag{3}$$

Zij is the normalized indicator matrix with scale free value, Xij is the value of indicator j for county i and j X is the mean value of indicator j.

2.2.7. Weighting the Indicators

After the elimination of scale bias, a common practice in constructing CI is to assign a weight to each sub-indicator, and then use certain aggregation functions to calculate CI for a set of individual indicators. The multivariate method of 'Principal Components Analysis' is suggested for computing CI. In the present study, principal componentsanalysis method was used to derive weighs for each of the indicators. The weights for sustainability dimensions were calculated.

Table 1. Total variance explained

Component	Eigenvalues	% of Variance	% Cumulative
1	8.576	37.28	37.28
2	7.413	32.22	69.51
3	4.26	18.55	88.06

Table 2. Indicators used in this research and their weight extracted with Principle Component Analysis(PCA)

Indicators	weightes
Soil fertility	0.95
Fertilizer application	0.65
Pesticide application	0.84
Water application	0.93
Area cultivated	0.82
Crop yeild	0.80
Income	0.92
Profit	0.78
Employment	0.85
Educated programs	0.74
Farmers' socia situation	0.91

$$CI = \Sigma I * W \tag{4}$$

CI: Composite index
I: Normalised indicators
W: weighte

   In this research, sustainability situation is divided into quadruple group which includes

ISDM (Interval Of Standard Deviation from the Mean). In this method, data were divided into four levels. A= Unsustainable, B= Relatively unsustainable, C= Relatively sustainable, D= Sustainable.
A: Min   A < Mean-St.d
B: Mean-St.d   B <Mean

C: Mean   C < Mean+St.d
D: Mean+St.d   D < Max

3. Results and Discussion

The results of descriptive analysis of the data showed that, in terms of age structure, about 14.5% of the farmers were 20-40 years, 25.5% were in 40-60 years and 60% in their 60s. In respect to literacy, about 75% of farmers were illiterate, 17% attended primary school, 6% of them had received secondary and high school education and 2% of them had high school graduation certificate. Income of farmers is also a crucial factor in achieving sustainable agriculture. And about 68.3% of the respondents have less than or equal to 1000000, 14.8% of them have 1000000-2000000, 6.3% of them have 2000000-3000000, 10.6% of them have 3000000 and more. The average farming land size and cultivated lands in the studied area were 10 and 4.5 ha, respectively. The average wheat production per hectare was 4.5 tons.

To assess sustainability of agricultural sector, indicators studied were: soil fertility, fertilizer application, pesticide application, water application, area cultivated, crop yeild, income, profit, employment, education programs, and farmers' social situation.

Agricultural sustainability is the aggregate of these indices, which are presented in Figure (3). The proposed methodology to compare and rank all 6 zones, with reference for each dimension in the first part and then to combine sub-indices to construct the final CI in the second part, were applied. The results are presented in Table 3. From the point of view of social sustainability, it is found that zone 4 is at the top and zone 1 is at the bottom of the ranking scale, while this zone is at the top in terms of economic dimension. Besides, zone 5 has the highest rank in terms of environmental, and zone 4 is placed in the second position. Social sustainability in zone 4 (0.97) is at the top of the ranking and zone 3(0.90), 5(0.89), 6(0.78), 2 (0.64) and 1 (0.61), respectively, are placed in the next positions. So, zone 4 and 3 are relatively sustainable but zone 2 is not from the point of view of social dimension. Zone 1(3.54) emerges as the most sustainable regarding economic dimension and zone 4(2.06) takes the second position and zone3 (1.26), 5(0.81), 6(0.36) and 2(0.30), respectively, are placed in the next positions. Besides, zone 4(2.68) has the highest rank in terms of environmental sustainability and zone 5(2.75), 2(1.91), 1(1.54), 3(0.81) and 6(0.38) are placed in the next positions.

Table 3. Sustainability situation of cropping systems

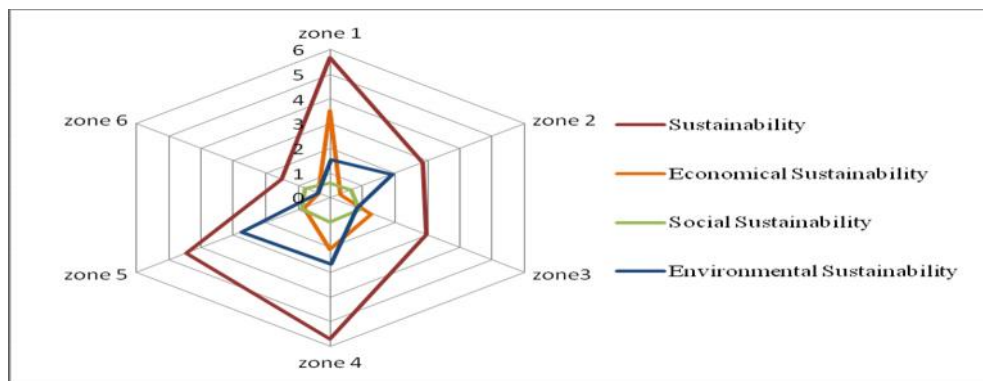|	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Sustainability rate	5.69	2.85	2.97	5.71	4.45	1.52
Economic sustainability	3.54	0.30	1.26	2.06	0.81	0.36
Social sustainability	0.61	0.64	0.90	0.97	0.89	0.78
Environmental sustainability	1.54	1.91	0.81	2.68	2.75	0.38

Fig. 3. The situation of sustainability dimensions in Marvdasht plain (source: paper findings)

It is sufficient here to note that zone 1 and 4 have the highest level of sustainability for CI, on the other extreme, zone 6 is the least sustainable (Table 3). Also, four classifications were chosen. A classificatory scheme is adopted which divides zones into four development categories: unsustainable, relatively unsustainable, relatively sustainable and sustainable. Category 1

(unsustainable) covers zone 6, category 2 (relatively unsustainable) has two zones 2 and 3 and category 3 (relatively sustainable) includes zone 5 and category 4 (sustainable) has two zones 1 and 4. The spatial pattern of agricultural sustainability based on the CI is presented in Figure 4b.
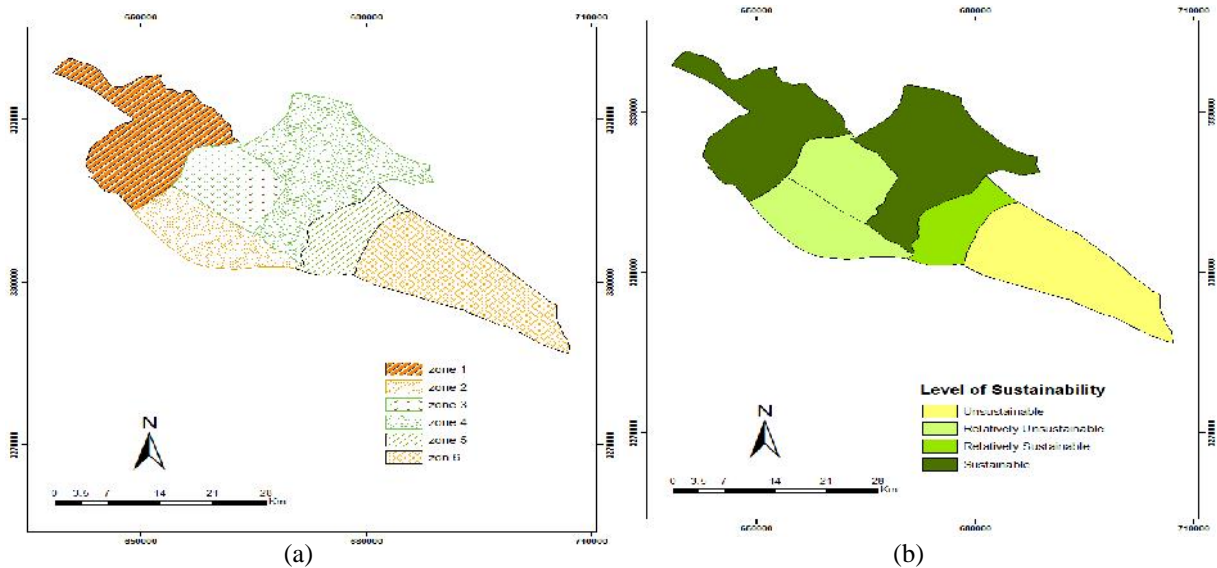

Fig. 4. Six zones in the study area (a), classifying levels of sustainability in Marvdasht Plain (b) (source: paper findings)

4. Discussion and Conclusion

The key contributions of this research are characterizing sustainability along three domains instead of just the single environmental domain common to current sustainability discussion. Attempts have been made to compile information on how the indices were formulated using nine steps, namely: selection, grouping, validation, judging, transforming normalizing, weighting, calculating and combining sub-indices.

This paper has examined the spatial pattern variations in the sustainability of Marvdasht plain with the application of a tool suggested for the assessment of the sustainability from a general and quantitative perspective. It purpose of CI is to display performance of agricultural regions along all the three dimensions of sustainability: social, economic and environmental, in order to provide a good guidance for decision-making. This gives users the ability to make the linkages between the different elements of sustainability. The indices developed for this research move a step closer to

both understanding sustainability more holistically and developing a method for policy makers.

According to the classifying CI, four categories were identified with zone 6 known as being unsustainable (Category 1), while two zones 2 and 3 were considered as belonging to the relatively unsustainable (category 2) and the zone 5 was identified as relatively sustainable (Category3) and the remaining zones (1,4) were classified as sustainable (Category 4). The results show that CI will be based on natural resources, human resources and on the relation between agriculture and the general economic development.

The result of this study can assist agricultural planners and policy-makers in identifying appropriate policies and monitoring the effectiveness of policy interventions on sustainability. In this case, to reach the ideal sustainability condition, the indicators which are in the unsustainable position should be improved. For example, in zone 2, economic sustainability is very low. So we should have optimized management methods should be implemented. Also in zone 6, environmental sustainability;

because of over-fertilize and over-irrigate their crops, are in the worst position. Thus, it is recommended that farmers are educated about best agricultural activities.

One final note, the study recommend that the usage of multidimensional and holistic CI for analyzing sustainability is extremely important. More specifically, it is a prerequisite for every judgment about sustainability condition, resource allocation, planning appropriate sustainability policies and executing those approaches, to reach sustainability.

Acknomledgements

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