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Full Length Research Paper

Agricultural sustainability and economic development: A cross – country analysis

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Abstract

In this paper, we assume that agricultural sustainability (AS) is an integral part of environmental sustainability, and geographical, cultural and social differences among countries are certainly important factors for development, but economic compulsion is an extremely important and decisive factor under the present 'borderless world'. This paper attempts to investigate the relationship between agricultural sustainability and economic development in a broader perspective by constructing inter-country agricultural sustainability index and economic development in a time series cross section pooled framework introducing dummy variables for continent as well as some threshold level of development at the country level. In this connection, we also try to test the validity of the Environmental Kuznets' Curve (EKC) across the countries.

Keywords: Agricultural Sustainability, Environmental Sustainability, Economic Development, Environmental Kuznets' Curve, Agricultural Sustainability Index.

INTRODUCTION

Development of modern agricultural practices over last few decades has raised questions on long run viability of current production systems particularly in the developing world. The spurt in food production across the world relies heavily on intensive use of chemical fertilizers, pesticides and related agricultural technology. There is hardly any doubt that uncontrolled and unscientific uses of all these agricultural inputs negatively affect the intrinsic value and life span of soil. These concerns have led to the development and proliferation of several alternative agricultural approaches like 'organic farming', 'shifting cultivation', etc. It is evident that uses of chemical fertilizers and pesticides increase agricultural yield in the short period, which partly helps the poor small and marginal farmers to struggle against abject poverty, but this very process nullifies their long run survival (Edwards et al. 1990, Altieri 1995, Gliessman 1998).

Despite the globalization of agricultural practices across the continents and much before the current trade related globalization begun just a decade ago, the developed countries have taken conscious and deliberate policies to minimize the permanent damage to the intrinsic fertility of soil. There is a widespread belief that developing countries have resorted to new agricultural technology for faster growth of food production without much attention to the long run fertility of soil. Notwithstanding these aberrations, secondary data as available from UNO, World Bank and other sources provide adequate support to the fact that rate of fertilizer use and pesticide application in the developing countries are nowhere near those in their developed counterparts.

In this paper, we assume that agricultural sustainability is an integral part of environmental sustainability, and geographical, cultural and social differences among countries particularly in rural areas play an overwhelming role in development, but economic compulsion is an extremely important and decisive factor under the present 'borderless world'. This paper attempts to investigate the relationship between agricultural sustainability, economic development and openness in a broader perspective by constructing inter-country agricultural sustainability index, openness and economic development in a time series cross section pooled framework. In this connection, we also try to test the validity of the Environmental Kuznets' Curve (EKC) across the countries. This paper has been divided into seven sections. In the next section, we have tried to elaborate the concepts of agricultural sustainability and EKC. In section III; we put forward limited literature. Sections IV talks on methodology and data, while results and analysis are dealt in Section V. Section VI reports summary and conclusions.

Agricultural sustainability and environmental Kuznets' curve

During the second half of the twentieth century world population became more than twofold, from approximately 2.5 billion in 1950 to 6.0 billion in 2000 and the demand placed on global agricultural production occurring out of population and income growth almost tripled. By 2050, world population has been projected to rise to between 9 and 10 billion. (Johnson 2000; United Nations 2001). The most difficult challenges will likely to be occurred during the next two or three decades as both population and income in many of the world's poorest countries may likely to grow rapidly. The demand for food arising out of income growth is also expected to rise. Very substantial increases in scientific and technical effort will be required, if growth in food production is to keep pace with growth in demand. So a second phase of Malthusian menace in a different sense is in the door.

Prior to the beginning of the twentieth century, almost all boosts in crop production took place as a consequence of increases in the area of cultivated land. By the end of the century almost all increases of the same were coming from increases in land productivity coupled with 'miracle seed'. In fact, a revolutionary transition occurred from a natural resource-based to a science-based system of agricultural production. In the currently developed countries, the beginning of this transition occurred in the latter half of the nineteenth century whereas in most developing countries, the transitions began in the second half of the twentieth century particularly since the 1960s.

Agricultural development policies and practices have led to indiscriminate use of external inputs as the means to increase food production in most countries - rich and poor, developed and developing. This process has led to unusual growth in consumption of chemical pesticides, inorganic fertilizers, irrigation water, HYV seeds, and associated energy waste for running tractors and other heavy machineries. All these may have been able to nullify the Malthusian proposition worldwide, but the rampant use of external inorganic inputs in most of the countries (excepting a few) has reached menacing proportions. In the developed world, over-application of inorganic fertilizers and inorganic pesticides has already led to environmental contamination of water supplies and soils (Conway and Pretty 1991; Bumb and Baanante 1996; NRC 1989). In the developing world, these external inputs have started substituting the natural processes and resources in an indiscriminate way thereby rendering them more vulnerable. Chemical pesticides have replaced biological, cultural and mechanical methods for controlling pests, weeds and diseases. Chemical fertilizers have been fast substituting the natural manures, composts and nitrogen-fixing crops. What is more, crop management decisions come from the pseudo-scientific input suppliers rather than from researchers, biologists and environmentalists in a situation of widespread illiteracy and perpetual poverty. The defects in the existing policy framework including obsession with immediate gains for survival have resulted in the over-exploitation of natural resources to attain a certain level of agricultural growth and reduction in rural poverty. With deforestation and the resulting degradation of land and depletion of groundwater resources, it has become more and more complicated to sustain agricultural growth and reduce rural poverty without imposing a heavy cost on society and on future generations.

In short, to achieve the goal of production enhancement, agricultural development policies and practices have successfully given emphasis to external inputs as the means to increase food production in the short run. This has led to growth in global production and consumption of pesticides, inorganic fertilizer etc. Under such a backdrop, agricultural sustainability appears as a new challenge not only to the developing world but also to the developed world as well. Avoiding all technical debates regarding the definition of agricultural sustainability, we accept sustainable agricultural practice as a method of cultivation, by which agricultural productivity can be increased imposing minimum possible burden on the future generation. In a sense, therefore, some consideration of inter-generational equality is at the core of economic rationality.

Environmental Kuznets' curve (EKC), on the other hand, explains how a nation's environmental quality will evolve if it makes a changeover from poverty to wealth over time. The accepted generalization is that pollution will first increase and then, if income continues to grow high, it will decline. Pollution initially grows when growth occurs in an extremely poor country, because the increased production creates pollutants and because the country, given its poverty, places a low priority on pollution control because 'environment' remains a luxury good still then. Once a country gains an adequate degree of wealth, its main concerns shift to protecting environment. If this income effect is sufficient, it will cause pollution to turn down.

Departed from the analysis of EKC of individual countries, Jha and Murthy (2003), have introduced the concept of Global Environmental Kuznets' Curve (GEKC), considering inter-country cross section data, which claims that "*at low income levels environmental degradation rises with the income level and at high levels of income there is a decline in the environmental degradation (like an inverted U curve)*". So one can argue in this context that, whether the developing countries (LDCs) should give up their development for the sake of world health.

It is very common in the existing literatures, to relate EKC with environmental sustainability (Grossman and Krueger, 1992, 1994; Radetzki, 1992; Panayotou, 1993; Grossman, 1995; Ehrlich and Holdren, 1971). In this paper, we have tried to examine the main proposition of GEKC in terms of agricultural sustainability. If the proposition of the GEKC is true then we can expect to observe lower agricultural sustainability for the developing countries and higher sustainability for developed countries, considering a inter country cross section analysis. It is common in the economic literature on EKC to relate environmental degradation with per capita income (PCI). But certain studies have argued that factors related to production are the possible causes behind environmental degradation (Grossman and Krueger, 1992, 1994; Radetzki, 1992; Panayotou, 1993; Grossman, 1995). That is why, we can observe an inverted 'U' relation between PCI and SO_2 emission but the same relation does not hold good for every pollutant. For this we take a deliberate deviation from the main theory of EKC. We accept Human Development Index (HDI) instead of PCI and Agricultural Sustainability Index (ASI) instead of any particular pollutant in order to asses the proposition of GEKC.

Overview of literature

The common belief is that the degree and level of dependence of poor countries on their natural resources such as soil, water, forest, animals and fisheries are so strong that they hardly care to maintain their natural resource base for their future survival. In a sense, the western concept of environment appears to be a luxury commodity here. A few foresighted thinkers and economists like Pigou, Baumol and Oates, Dasgupta and Heal, first started thinking about environmental impact on economy who mainly deal with abstract theoretical possibilities and limitations of the environmental economics at the global level. Some works have been done in the context of Western agriculture (Schumacher, 1973; Jackson, 1980; Rodale, 1983; Crissman et al., 1994; Henry, 1996) on agricultural sustainability. In the case of developing countries, Stoorvogal and Smaling (1990), Chattaopadhyay and Ghosh (1994), Singh and Singh (1995), Bumb and Baanante (1996) and Henao and Baanante (1999) have done related works on problems of sustainable agriculture. Although there is no exact research work in our knowledge dealing with the issues raised here, the following works appear to be helpful for our study as a starting point: Chakravorty (1991), Swaminathan (1992), Chopra (1993), Chattopadhyay and Ghosh (1994), Rao (1994), Singh and Singh (1995), Roy (1996), Wilson and Tisdell (2001), and Ali (2003).

The EKC concept came into view in the early 1990s with Grossman and Krueger's (1991) path breaking study of the potential impacts of NAFTA and Shafik and Bandyopadhyay's (1992) background study for the 1992 World Development Report. A number of studies have proposed theoretical analysis on interaction of preferences and technology resulting in different time paths of environmental quality. Most of these studies generate an inverted U shape curve of pollution intensity but there is no certainty about this. The result may vary with the assumptions made in different models and the values of particular parameters. Lopez (1994) and Selden and Song (1995) assumes that pollution is generated by production and not by consumption. John and Pecchenino (1994), John et al. (1995), and McConnell (1997) constructed a consumption based model of EKC. Stokey (1998) allows endogenous technical change and so on.

Recent empirical evidences show that the inverse 'U' relationship of GEKC does not hold well under certain alteration in the assumptions (Jha and Murthy; 2003, 2006). Some other critics of the proposition of EKC are Ansuategi et al., 1998; Arrow et al., 1995; Ekins, 1997; Pearson, 1994; Stern et al., 1996; Stern, 1998, etc. Under such a background, we intend to test the proposition of GEKC in terms of agricultural sustainability.

METHODOLOGY AND DATA

Our *modus operandi* for arriving at a better understanding of the relation between agricultural sustainability and economic development is as follows. We use the method of Principal Components Analysis (PCA) to construct an Agricultural Sustainability Index (ASI) for each country. We then use UNDP approach to construct Human Development Index (HDI). Then we try to compare the ranking of countries according to the HDI ranks with their ranking according to their ASI. Finally, we try to classify selected countries into different income groups following *World Bank Atlas Method* in order to understand the relationship between economic development and agricultural sustainability of these countries. Our choices of variables and also the choice of countries are limited by the availability of data. We have tried to analyze all these in three different cross section time points, viz. 1990, 1995 and 2005. Some missing data are replaced by one or two period lagged data.

Table 1. Variables and their effects on agricultural sustainability

Variable	Effect on sustainability
FC	Non-Supportive
AM	Supportive
COMEN	Non-Supportive
IRRI	Supportive
CO2PC	Non-Supportive

Constructing ASI – The principal components analysis

PCA is a way to recognize patterns in data, and to express the data in such a way as to emphasize on their similarities and differences. Since patterns in data can be hard to find in data of high dimension, where the luxury of graphical representation is not available, PCA is a powerful tool for analyzing such data. The goal of the PCA is to expose how different variables change in relation to each other, or how they are related. This can be done by converting correlated original variables into a new set of uncorrelated underlying variables (termed as *principal components*) using the covariance matrix, or correlation matrix. The principal components intend to measure different "statistical dimensions" in the dataset, that is why we use uncorrelated principle components. The new variables are linear combinations of the original ones. These new variables are sorted into descending order considering the amount of variance that they account for in the original set of variables. PCA calculates the *eigenvalues* and their corresponding *eigenvector*s and each *eigenvalue* represents the total remaining variance that the corresponding new variable accounts for. The elements of the eigenvector are the coefficients (*loadings*) used in the linear transformation of the original variables into the new variables. These *factor loadings* are considered as the weights of different variables.

In order to construct ASI, we consider the following variables:

FC: Fertilizer consumption (100 grams per hectare of arable land)

AM: Agricultural machinery (tractors per 100 hectares of arable land)

COMEN: Commercial energy use (kg of oil equivalent per capita)

IRRI: Irrigated land (% of crop land)

CO2PC: Per capita CO_2 emission (metric tons per capita).

To make the variable unit free and to neutralize the heterogeneity due to varied units, we divide all the values by the "all time highest value" (considering the period 1990-2000) of the corresponding variable from the group we are dealing with.

There is a widespread belief that sustainable agricultural practices are synonymous with ancient type of agricultural practices. But going back to the past in terms of agricultural practices will certainly pose some burden on the future generation by huge amount of productivity loss. At this point we assume that intensive use of agricultural machinery and irrigation are supportive to the agricultural sustainability. Definitely, use of modern technology in the field, produces ground polluting waste and emissions, which decrease sustainability of agriculture. That is why we consider commercial energy use per capita and CO_2 emission as balancing proximities while constructing ASI. The effects of the considered variables on agricultural sustainability are shown in table 1.

To make the effects of all variables unidirectional, we consider inverse of the unit free values of the variables FC, COMEN and CO2PC and direct unit free values of AM and IRRI. What we have assured in this way is that higher ASI index of any country means better position in country listing in terms of agricultural sustainability. Now,

(1) $ASI_{it} = \sum W_{kt} X_{kit}$

Where ASI_{it} = Agricultural Sustainability Index of the i^{th} country in t^{th} time point,

W_{kt} = weight of the k^{th} variable in t^{th} time point,

X_{kit} = unit free value of the k^{th} variable for the i-th country in t^{th} time point.

Weights of the variables derived from PCA are shown in Table 2 below.

Constructing HDI – The UNDP approach

The UNDP methodology for calculating HDI considers three separate sub-indices: (i) life expectancy, (ii) educational attainment, and (iii) GDP, which are combined to form the HDI. To consider the gender bias in the development process of a country, each of the first two sub-indices are represented by female life expectancy at birth (LEF) and male life expectancy at birth (LEM); and male literacy rate (MLR) and female literacy rate (FLR) respectively (see Table 3).

Table 2. Weights of the variables affecting agricultural sustainability

Year	Variable	Weights
	FC	0.67
	AM	-0.52
1990	COMEN	0.76
	IRRI	-0.29
	CO2PC	0.79
	FC	0.70
	AM	-0.54
1995	COMEN	0.72
	IRRI	-0.32
	CO2PC	0.81
	FC	0.70
	AM	-0.53
2000	COMEN	0.72
	IRRI	-0.32
	CO2PC	0.81

Table 3. Indices and variables of HDI

Index	Variable	
Life Expectancy	1.	LEF
	2.	LEM
Educational Attainment	1.	MLR
	2.	FLR
GDP	Per Capita Income (PCI)	

To transform a raw variable (say x) into a unit-free index between 0 and 1 (which allows different indices to be added together), the following formula has been used:

(2) x-index = (x – min(x)) / (max(x) – min(x)),

Where min(x) and max(x) are the lowest and highest values of the variable x respectively. To account for the diminishing marginal utility of income, we use a log formula to discount GDP per capita in the calculation of the GDP index. So,

(3) $\text{GDP-index}_{it} = [\ln (PCI)_{it} - \min \ln (PCI)_t] / [\max \ln (PCI)_t - \min \ln (PCI)_t]$,

where GDP-index_{it} = GDP index of the i^{th} country in t^{th} period,

$\ln (PCI)_{it}$ = natural logarithm of the i^{th} country's PCI at PPP in t^{th} period,

$\max \ln (PCI)_t$ and $\min \ln (PCI)_t$ = largest and smallest values of natural logarithm of PCI at PPP in t^{th} period respectively.

Now as per our formulation the HDI is the simple arithmetic mean of all indices. So,

(4) $HDI_{it} = 1/5\ (\text{LEF-index}_{it} + \text{LEM-index}_{it} + \text{MLR-index}_{it} + \text{FLR-index}_{it} + \text{GDP-index}_{it})$

World Bank atlas method – Classification of countries

In calculating per capita income of different countries in U.S. dollars for certain operational purposes, the World Bank employs the Atlas conversion factor. The principle of the Atlas conversion factor is to decrease the impact of exchange rate fluctuations in the cross-country comparison of national incomes. The following formulas describe the calculation of the Atlas conversion factor for year t:

(5) $e^*_t = 1/3[e_{t-2}\{(p_t/p_{t-2}) / (p^{S\$}_t/p^{S\$}_{t-2})\} + e_{t-1}\{(p_t/p_{t-1}) / (p^{S\$}_t/p^{S\$}_{t-1})\} + e_t]$

and the calculation of PCI in U.S. dollars for year t :

(6) $Y^{\$}_t = (Y_t / N_t) / e^*_t$

where e^*_t is the Atlas conversion factor (national currency to the U.S. dollar) for year t, e_t is the average annual exchange rate (national currency to the U.S. dollar) for year t, p_t is the GDP deflator for year t, $p^{S\$}_t$ is the SDR deflator in U.S. dollar terms for year t, $Y^{\$}_t$ is the Atlas PCI in U.S. dollars in year t, Y_t is current GNI (local currency) for year t, and N_t is the midyear population for year t.

According to World Bank criterion following World

Table 4. Year-Wise criterion of agricultural sustainability status

Year	ASI	ASS
1990	ASI ≤ 48.86	Low
	48.86 < ASI ≤ 108.80	Lower Middle
	108.80 < ASI ≤ 285.67	Upper Middle
	ASI > 285.67	High
1995	ASI ≤ 61.80	Low
	61.80 < ASI ≤ 134.17	Lower Middle
	134.17 < ASI ≤ 406.18	Upper Middle
	ASI > 406.18	High
2000	ASI ≤ 55.93	Low
	55.93 < ASI ≤ 120.55	Lower Middle
	120.55 < ASI ≤ 379.97	Upper Middle
	ASI > 379.97	High

Table 5. Comparison between income status and agricultural sustainability status of individual countries

Sl No.	Country	Income Status	ASS 90	ASS 95	ASS 2000
1	Albania	Lower middle income	lower middle	high	high
2	Algeria	Lower middle income	upper middle	high	high
3	Angola	Lower middle income	high	high	high
4	Argentina	Upper middle income	high	upper middle	upper middle
5	Armenia	Lower middle income	upper middle	high	high
6	Australia	High income	upper middle	Lower middle	lower middle
7	Austria	High income	low	low	low
8	Bahrain	High income:	low	low	low
9	Bangladesh	Low income	high	high	high
10	Belarus	Lower middle income	low	lower middle	lower middle
11	Belgium	High income	low	low	low
12	Bolivia	Lower middle income	high	high	high
13	Brazil	Lower middle income	upper middle	lower middle	lower middle
14	Bulgaria	Lower middle income	low	upper middle	upper middle
15	Cameroon	Low income	high	high	high
16	Canada	High income	lower middle	lower middle	lower middle
17	Chile	Upper middle income	lower middle	lower middle	low
18	China	Lower middle income	lower middle	lower middle	lower middle
19	Colombia	Lower middle income	upper middle	lower middle	lower middle
20	Congo, DR	Low income	high	high	high
21	Congo, Rep.	Low income	high	high	upper middle
22	Croatia	Upper middle income	lower middle	lower middle	lower middle
23	Cyprus	High income	low	low	low
24	Denmark	High income	low	low	low
25	Dominican Rep.	Lower middle income	upper middle	lower middle	lower middle
26	Ecuador	Lower middle income	upper middle	upper middle	upper middle

Table 5. Continued……….

Sl No.	Country	Income Status	ASS 90	ASS 95	ASS 2000
27	Egypt	Lower middle income	upper middle	lower middle	lower middle
28	El Salvador	Lower middle income	upper middle	upper middle	upper middle
29	Estonia	Upper middle income	low	upper middle	upper middle
30	Ethiopia	Low income	high	high	high
31	Finland	High income	low	low	low
32	France	High income	low	low	low
33	Gabon	Upper middle income	high	high	high
34	Georgia	Lower middle income	lower middle	upper middle	upper middle
35	Germany	High income	low	low	low
36	Ghana	Low income	high	high	high
37	Greece	High income	low	low	low
38	Guatemala	Lower middle income	upper middle	upper middle	upper middle
39	Honduras	Lower middle income	high	upper middle	upper middle
40	Hungary	Upper middle income	lower middle	lower middle	lower middle
41	India	Low income	upper middle	upper middle	upper middle
42	Indonesia	Lower middle income	upper middle	upper middle	upper middle
43	Iran	Lower middle income	lower middle	lower middle	lower middle
44	Israel	High income	low	low	low
45	Italy	High income	low	low	low
46	Jamaica	Lower middle income	lower middle	lower middle	lower middle
47	Japan	High income	low	low	low
48	Jordan	Lower middle income	upper middle	lower middle	lower middle
49	Kazakhstan	Lower middle income	upper middle	high	high
50	Kenya	Low income	high	high	high
51	Korea, Rep.	High income	low	low	low
52	Kyrgyz Rep.	Low income	upper middle	upper middle	upper middle

Table 5. Continued……….

Sl. No.	Country	Income Status	ASS 90	ASS 95	ASS 2000
53	Latvia	Upper middle income	lower middle	upper middle	upper middle
54	Lebanon	Upper middle income	lower middle	lower middle	low
55	Lithuania	Upper middle income	lower middle	lower middle	lower middle
56	Malaysia	Upper middle income	lower middle	low	low
57	Mexico	Upper middle income	lower middle	lower middle	lower middle
58	Moldova	Low income	lower middle	lower middle	high
59	Morocco	Lower middle income	upper middle	upper middle	upper middle

Table 5. Continued……….

60	Mozambique	Low income	high	high	high
61	Nepal	Low income	high	high	high
62	Netherlands	High income	low	low	low
63	New Zealand	High income	low	low	low
64	Nicaragua	Low income	high	high	high
65	Nigeria	Low income	high	high	high
66	Oman	Upper middle income	low	low	low
67	Pakistan	Low income	upper middle	upper middle	upper middle
68	Panama	Upper middle income	high	upper middle	lower middle
69	Paraguay	Lower middle income	high	high	upper middle
70	Peru	Lower middle income	upper middle	upper middle	upper middle
71	Philippines	Lower middle income	upper middle	upper middle	upper middle
72	Poland	Upper middle income	lower middle	low	lower middle
73	Portugal	High income	lower middle	lower middle	lower middle
74	Romania	Lower middle income	lower middle	lower middle	upper middle
75	Russia	Upper middle income	lower middle	upper middle	upper middle
76	Saudi Arabia	High income	low	low	low
77	Senegal	Low income	high	high	high
78	South Africa	Upper middle income	lower middle	lower middle	lower middle
79	Spain	High income	lower middle	low	low
80	Sri Lanka	Lower middle income	high	upper middle	upper middle
81	Sudan	Low income	high	high	high
82	Switzerland	High income	low	low	low
83	Syria	Lower middle income	upper middle	lower middle	lower middle

Table 5. Continued……….

Sl No.	Country	Income Status	ASS 90	ASS 95	ASS 2000
84	Tajikistan	Low income	lower middle	upper middle	high
85	Tanzania	Low income	high	high	high
86	Thailand	Lower middle income	upper middle	lower middle	lower middle
87	Tunisia	Lower middle income	upper middle	upper middle	upper middle
88	Turkey	Upper middle income	lower middle	lower middle	lower middle
89	Turkmenistan	Lower middle income	lower middle	lower middle	lower middle
90	UAE	High income	lower middle	upper middle	upper middle
91	Ukraine	Lower middle income	low	low	low
92	UK	High income	low	low	low
93	USA	High income	low	low	low
94	Uruguay	Upper middle income	upper middle	upper middle	lower middle
95	Venezuela, RB	Upper middle income	low	low	lower middle
96	Vietnam	Low income	high	upper middle	upper middle
97	Yemen, Rep.	Low income	high	high	high
98	Zambia	Low income	high	high	high
99	Zimbabwe	Low income	upper middle	upper middle	upper middle

Source:1. India Infrastructure Database 2005, Volume 1, Bookwell Publishers Pvt.Ltd., New Delhi.
2. World Bank List of Economies, available at www.worldbank.org, accessed on October 2, 2006.
3. Own Calculations.

Table 6. Change of sustainability status of countries of different income status in the period 1990 - 2000

Income \ ASS	Remain Stagnant	Degrade Standard	Upgrade Standard
Low	Bangladesh, Cameroon, Congo DR, Ethiopia, Ghana, India, Kenya, Kyrgyz Rep., Mozambique, Nepal, Nicaragua, Nigeria, Pakistan, Senegal, Sudan, Tanzania, Yemen Rep., Zambia, Zimbabwe.	Congo Rep., Vietnam.	Moldova, Tajikistan.
Lower Middle	Angola, Bolivia, China, Ecuador, El Salvador, Guatemala, Indonesia, Iran, Jamaica, Morocco, Peru, Philippines, Tunisia, Turkmenistan, Ukraine.	Brazil, Colombia, Dominican Rep., Egypt, Honduras, Jordan, Paraguay, Sri Lanka, Syria, Thailand.	Albania, Algeria, Armenia, Belarus, Bulgaria, Georgia, Kazakhstan, Romania.
Upper Middle	Croatia, Gabon, Hungary, Lithuania, Mexico, Oman, Poland, South Africa, Turkey.	Argentina, Chile, Lebanon, Malaysia, Panama, Uruguay.	Estonia, Latvia, Russia, Venezuela RB.
High	Austria, Bahrain, Belgium, Canada, Cyprus, Denmark, Finland, France, Germany, Greece, Israel, Italy, Japan, Korea Rep. Netherlands, New Zealand, Portugal, Saudi Arab, Switzerland, UK, USA.	Australia, Spain.	UAE.

Source: Own calculations

Bank Atlas Method, we divide the selected countries into four income groups. The groups are: low income, $825 or less; lower middle income, $826–3,255; upper middle income, $3,256–10,065; and high income, $10,066 or more. To avoid the complexity, we consider World Bank list of economies (July 2005) for this classification, with the assumption that there is no major revolutionary change in the countries' income level in only a decade.

RESULTS AND ANALYSIS

As we have stated earlier, the aim of this paper is to find out the relation between agricultural sustainability and economic development. It should be noted here that we observe no significant relation between openness and agricultural sustainability. That is why we do not present the statistical exercise we have done to relate openness and agricultural sustainability. So, we have confined ourselves in analyzing the relation between economic development and agricultural sustainability as well as human development and agricultural sustainability.

Economic development and agricultural sustainability

In this sub-section we have tried to relate income status of the countries with agricultural sustainability status. Table 5 presents a clear picture regarding this. We have divided the agricultural sustainability status (ASS) of countries into four categories, viz. low, lower middle, upper middle and high. The criterion of such division is given in table 4. This is done simply by partitioning the whole set of agricultural sustainability indices of different countries into four equal part in terms of their quartile values.

Table 5 shows that, expect Albania, almost all other countries, either stick to their sustainability status or degrade their status during the decade. Albania alone has shown a remarkable improvement in terms of agricultural sustainability. Some other countries like, Belarus, Estonia, Georgia Kazakhstan etc. slightly improve their status in terms of agricultural sustainability. What is important, World's most developed countries' performances are not quite satisfactory in terms of agricultural sustainability, while comparing with their

Table 7. Position of the countries of different income status, stagnant at their sustainability status

Income Status \ ASS	Low	Lower Middle	Upper Middle	High
Low			Kyrgyz Rep., Pakistan, Zimbabwe.	Bangladesh, Cameroon, Congo DR, Ethiopia, Ghana, India, Kenya, Mozambique, Nepal, Nicaragua, Nigeria, Senegal, Sudan, Tanzania, Yemen Rep., Zambia,
Lower Middle	Ukraine.	China, Iran, Jamaica, Turkmeni stan,	Ecuador, El Salvador, Guatemala, Indonesia, Morocco, Peru, Philippines, Tunisia,	Angola, Bolivia,
Upper Middle	Oman,	Croatia, Hungary, Lithuania, Mexico, Poland, South Africa, Turkey.		Gabon,
High	Austria, Bahrain, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Israel, Italy, Japan, Korea Rep. Netherlands, New Zealand, Saudi Arab, Switzerland, UK, USA.	Canada, Portugal,		

Source: Own calculations

developing counterparts.

Table 6 presents a clearer picture about the relative position changing of the countries in terms of their agricultural sustainability status. This table shows that only 15 countries out of 99 selected countries upgrade their agricultural sustainability standard during the period 1990 – 2000. Out of these 15 countries only one country (viz. UAE), belongs to the high income group. Among the countries who have upgraded their position in terms of agricultural sustainability status, most of the countries belong to the lower middle income group. Only two low income countries and four upper middle income countries have improved their status in terms of agricultural sustainability. On the other hand, only twenty countries have degraded in terms of their agricultural sustainability status over decade. Out of these twenty countries two belong to low income status, ten belong to lower middle income status, six belong to upper middle income status and two belong to high income group.

We have observed from table 6 that 64 countries out of 99 remain stagnant at their agricultural sustainability status during the decade. We compare the income status of these sixty four countries with their agricultural sustainability position in Table 7. In this table we have observed that most of the low income countries (19) remain stagnant at high agricultural sustainability position and most of the high income countries (21) remain stagnant at low agricultural sustainability position during the period 1990 - 2000. On the contrary, most of the lower middle income countries remain stagnant at upper middle agricultural sustainability position and most of the upper middle income countries remain stagnant at lower

Table 8. Bi-Variate Frequency Distribution Showing Relation between Economic Development and Agricultural Sustainability (Year 1990)

ASS \ Income Status	Low	Lower Middle	Upper Middle	High	Total
Low	00	03	03	19	25
Lower Middle	02	07	12	04	25
Upper Middle	04	18	01	01	24
High	17	05	03	00	25
Total	23	33	19	24	99

Source: Own Calculations

Table 9. Bi-Variate frequency distribution showing relation between economic development and agricultural sustainability (year 1995)

ASS \ Income Status	Low	Lower Middle	Upper Middle	High	Total
Low	00	01	04	20	25
Lower Middle	01	13	08	03	25
Upper Middle	06	12	06	01	25
High	16	07	01	00	24
Total	23	33	19	24	99

Source: Own calculations

Table 10. Bi-Variate Frequency Distribution Showing Relation between Economic Development and Agricultural Sustainability (year 2000)

ASS \ Income Status	Low	Lower Middle	Upper Middle	High	Total
Low	00	01	04	20	25
Lower Middle	00	12	10	03	25
Upper Middle	06	14	04	01	25
High	17	06	01	00	24
Total	23	33	19	24	99

Source: Own Calculations

middle agricultural sustainability position.

Table 8, 9 and 10 bring a more comprehensive picture of the relationship between economic development and agricultural sustainability. This is a two way table showing the number of countries under each income group as well as agricultural sustainability category.

Table 6 reveals that, in the 1990, out of 24 high income countries 19 have low agricultural sustainability status (almost 79.17 %.) and out of 23 low income countries 17 have high agricultural sustainability status (almost 73.91 %). In 1995 and 2000, almost 83 percent high income countries have fallen into the low agricultural sustainability category 69.57 percent and 73.91 percent low income countries have fallen in the high agricultural sustainability category respectively. Interestingly, no high income country has shown the best performance or no low income country has shown the worst performance in terms of agricultural sustainability.

Human development and agricultural sustainability

Let us now see the relation between human development and agricultural sustainability. We have already constructed Human Development Index (HDI) following UNDP approach and Agricultural Sustainability Index (ASI) following PCA. We have derived Human Development Rank (HDR) from HDI and Agricultural Sustainability Rank (ASR) from ASI for three cross section time points (1990, 1995, and 2000). HD Rank and AS Rank have been presented in Table 11.

To understand the relation between Agricultural Sustainability and Human Development, we have plotted

Table 11. Table Showing the Agricultural Sustainability Rank and Human Development Rank of Selected Countries (1990 – 2000)

Sl. No.	Country	ASR 1990	HDR 1990	ASR 1995	HDR 1995	ASR 2000	HDR 2000
1	Albania	56	64	24	71	20	63
2	Algeria	28	84	18	83	24	83
3	Angola	8	88	8	88	2	86
4	Argentina	16	38	34	31	45	32
5	Armenia	36	45	23	47	23	46
6	Australia	40	8	58	8	59	8
7	Austria	84	14	80	13	81	10
8	Bahrain	98	51	98	42	93	42
9	Bangladesh	13	103	17	102	16	100
10	Belarus	88	32	68	45	74	45
11	Belgium	96	13	96	11	96	13
12	Bolivia	6	85	12	85	12	82
13	Brazil	44	68	50	68	55	70
14	Bulgaria	83	41	47	37	46	40
15	Cameroon	5	95	9	96	15	96
16	Canada	55	4	65	5	65	7
17	Chile	59	43	70	30	76	33
18	China	60	75	67	73	66	73
19	Colombia	49	59	61	51	52	49
20	Congo,DR.	2	100	1	103	1	105
21	Congo, Rep.	19	96	20	95	27	93
22	Croatia	64	30	73	35	72	36
23	Cyprus	79	24	84	23	78	23
24	Denmark	90	17	87	18	83	18
25	Dominican Rep.	42	72	53	74	54	75
26	Ecuador	37	65	48	66	49	66
27	Egypt	48	91	60	90	62	89
28	El Salvador	29	77	40	75	44	76
29	Estonia	76	40	43	41	43	38
30	Ethiopia	4	108	4	108	10	108
31	Finland	89	18	83	17	84	16
32	France	87	9	85	10	86	9
33	Gabon	12	76	2	79	3	80
34	Georgia	54	31	25	43	33	44

Table 11. Continued………

Sl No.	Country	ASR 1990	HDR 1990	ASR 1995	HDR 1995	ASR 2000	HDR 2000
35	Germany	93	16	89	16	89	14
36	Ghana	10	92	7	91	8	90
37	Greece	81	22	79	24	82	25
38	Guatemala	30	89	37	87	39	85
39	Honduras	17	82	32	84	36	84
40	Hungary	72	34	66	36	70	35
41	India	32	94	39	94	41	92
42	Indonesia	38	80	49	77	47	77
43	Iran	57	83	62	81	67	79
44	Israel	86	25	90	25	92	24

Table 11. Continued………

45	Italy	82	12	82	12	87	15
46	Jamaica	63	60	71	56	68	59
47	Japan	94	1	93	1	94	1
48	Jordan	47	66	57	61	56	60
49	Kazakhstan	25	47	10	59	6	58
50	Kenya	18	90	19	93	21	95
51	Korea, Rep.	85	44	95	32	95	29
52	Kyrgyz Rep.	35	50	29	62	26	62
53	Latvia	65	35	27	50	35	39
54	Lebanon	52	73	74	67	75	69
55	Lithuania	53	27	51	38	53	37
56	Malaysia	69	61	88	53	88	50
57	Mexico	58	55	54	46	61	41
58	Moldova	62	48	55	63	9	64
59	Morocco	26	93	31	92	31	91
60	Mozambique	1	107	3	107	5	107
61	Nepal	3	104	11	104	14	103
62	Netherlands	97	6	97	9	97	12
63	New Zealand	77	19	92	19	98	20
64	Nicaragua	24	87	22	86	19	87
65	Nigeria	22	102	14	101	13	102
66	Oman	92	79	91	76	90	74

Table 11. Continued………

Sl No.	Country	ASR 1990	HDR 1990	ASR1995	HDR 1995	ASR 2000	HDR 2000
67	Pakistan	31	98	36	98	34	98
68	Panama	41	53	42	39	50	43
69	Paraguay	15	58	21	54	29	54
70	Peru	27	67	35	65	37	65
71	Philippines	34	63	41	60	42	57
72	Poland	71	37	76	34	73	31
73	Portugal	66	36	72	29	71	30
74	Romania	73	46	52	40	48	47
75	Russia	51	42	28	55	25	53
76	Saudi Arabia	80	70	75	70	77	68
77	Senegal	11	106	13	106	17	106
78	South Africa	61	69	63	80	57	88
79	Spain	70	20	78	22	79	22
80	Sri Lanka	21	62	26	57	30	55
81	Sudan	9	101	5	97	4	97
82	Switzerland	91	2	86	2	85	4
83	Syria	46	81	59	82	58	81
84	Tajikistan	67	56	38	64	22	72
85	Tanzania	7	99	6	100	7	99
86	Thailand	45	57	64	49	64	51
87	Tunisia	33	78	33	78	38	78
88	Turkey	50	71	56	69	60	67
89	Turkmenistan	74	49	69	58	63	61
90	Ukraine	68	39	46	52	28	52
91	UAE	99	52	99	48	99	56
92	UK	95	15	94	15	91	19
93	USA	78	10	81	14	80	11
94	Uruguay	39	33	44	33	51	34
95	Venezuela, RB	75	54	77	44	69	48
96	Vietnam	23	74	30	72	32	71
97	Yemen, Rep.	20	105	16	105	18	104

Table 11. Continued………

98	Zambia	14	97	15	99	11	101
99	Zimbabwe	43	86	45	89	40	94

Source: India Infrastructure Database 2005, Volume 1, Bookwell Publishers Pvt. Ltd., New Delhi. And Own Calculations.

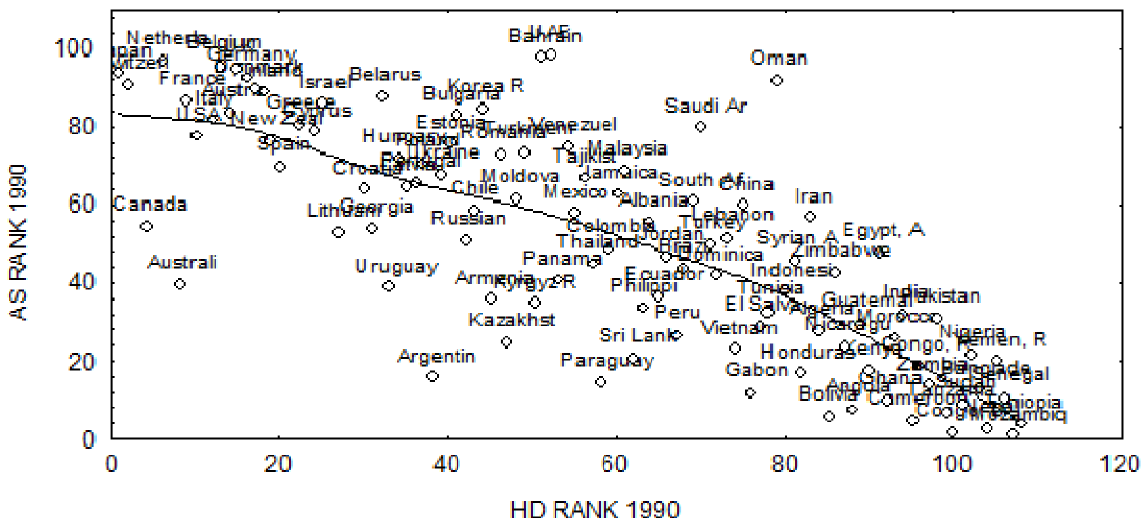

Figure 1. Scatterplot showing relation between human development and agricultural sustainability (year 1990)

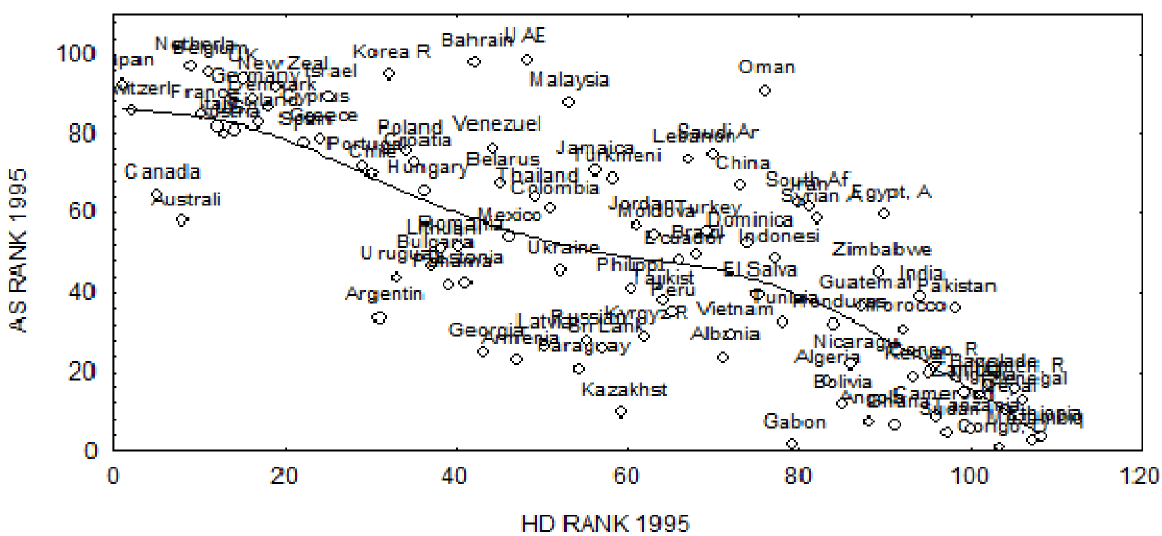

Figure 2. Scatterplot showing relation between human development and agricultural sustainability (year 1995)

HD Rank and AS Rank in the scatter plots. Figure 1, 2 and 3 respectively show the above said relation of 1990, 1995 and 2000. The trend curves of the three scatter plots have been drawn following least square method.

The trend curves definitely depict the negative relationship between agricultural sustainability and human development. To avoid the distribution specificity of the data set, we prefer to perform all the statistical exercises with AS rank and HD rank, instead of accepting AS score and HD score. But here we present three scatter plots showing relation between HD score and AS score (Figure 4, 5 and 6).

In figures 4, 5 and 6, we also observe a negative relation between human development and agricultural sustainability. The relationship is not as strong as we have observed in case of HD rank and AS rank. In this connection, we have argued that our derived AS scores of different countries are so varied in nature that unless one go through the outlier analysis, it is impossible to find out the exact relation between AS score and HD score.

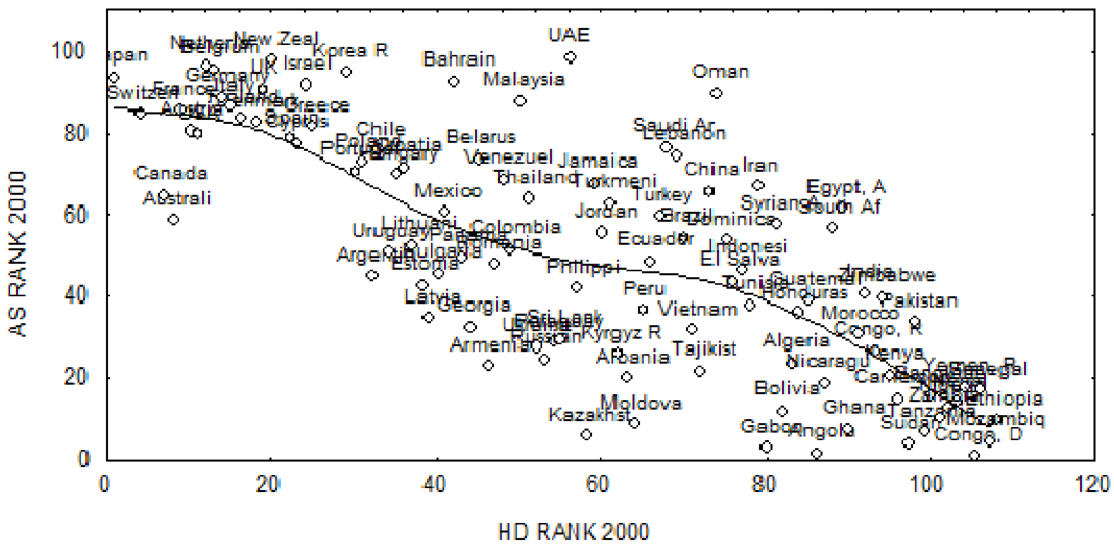

Figure 3. Scatterplot showing relation between human development and agricultural sustainability (year 2000)

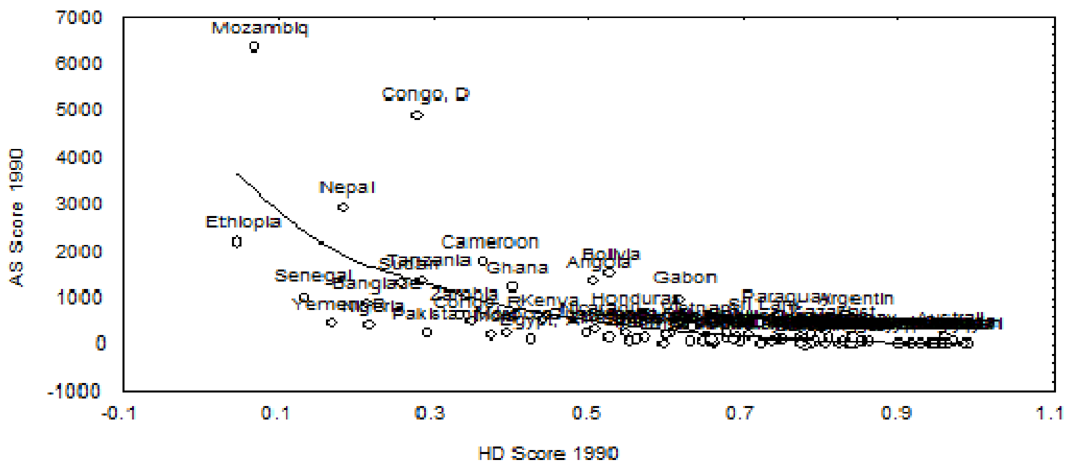

Figure 4. Scatterplot showing relation between HD score and AS score (year 1990)

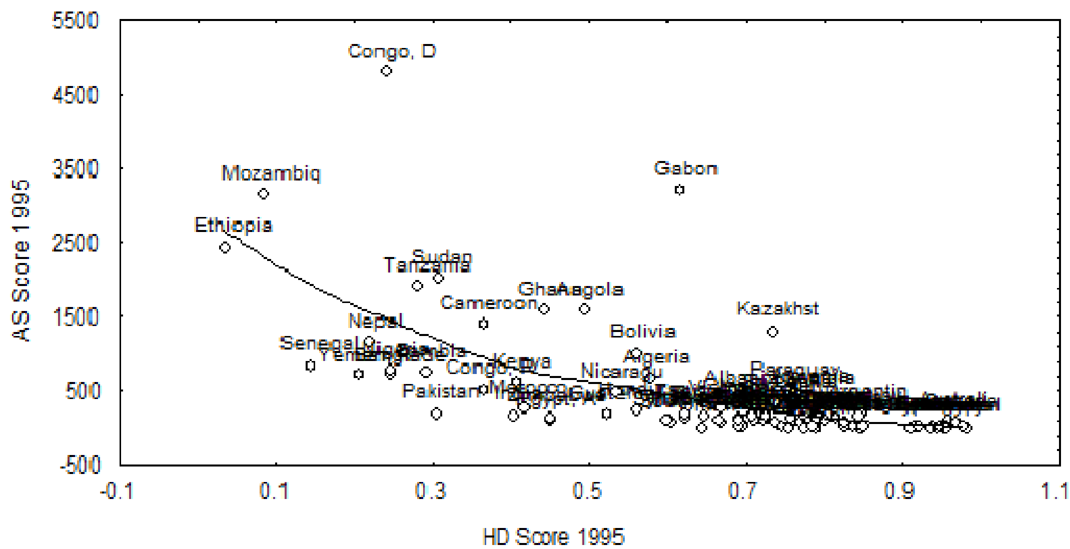

Figure 5. Scatterplot showing relation between HD score and AS score (year 1995)

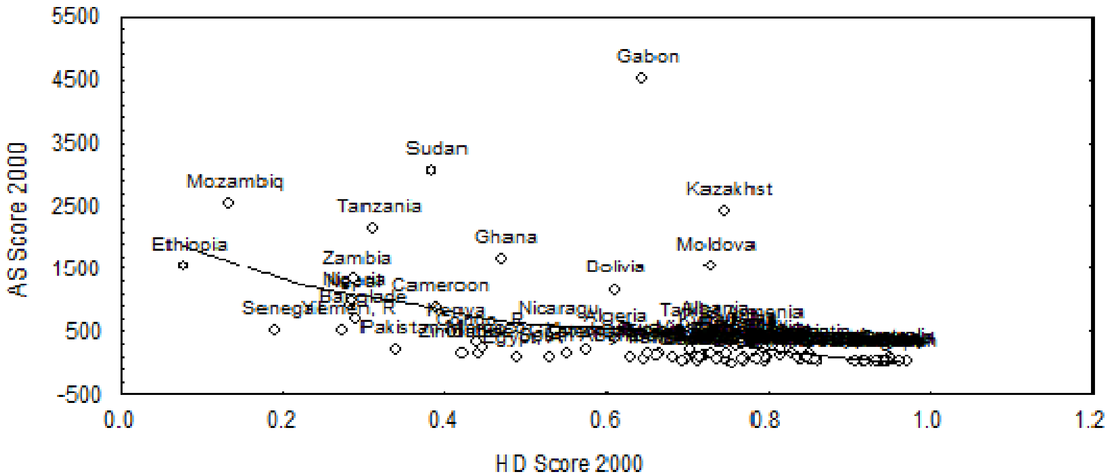

Figure 6. Scatterplot showing relation between HD score and AS score (year 2000) (Angola and Congo DR are excluded as outlier)

Table 12. Non Parametric Test (Spearman's Rank Correlation Coefficient) for Relationship between AS Rank and HD Rank

Year	Spearman R	t-Value
1990	-0.78	-12.18
1995	-0.75	-11.24
2000	-0.74	-10.93

Source: Own calculations

So, we have preferred to confine our analysis to non - parametric pattern of testing.

For a better understanding the degree of association between HD Rank and AS Rank, we carried out a simple non – parametric test, Spearman's Rank Correlation coefficient. The results of the test have been provided in Table 12 below.

From the above table it is clear that agricultural sustainability and human development is negatively associated and the degree of association is quite strong between two.

CONCLUSION

Two main contributions of this paper are to construct Agricultural Sustainability Index, applying PCA and to estimate the relationship between agricultural sustainability and development status of countries. In this context we have tried to examine the main proposition of GEKC. It is clear from the analysis that there may exist a negative relationship between agricultural sustainability and development. No matter, whether the development of the countries is measured in terms of PCI or overall human development. We have observed the contribution of the developed countries on world agricultural sustainability degradation is more that that of their developing counterparts. This finding definitely opposes the main proposition of GEKC in terms of agricultural sustainability. But use of average data for a country as a whole on matters of agricultural or environmental issue may conceal the real variance across various agro-geographical areas even in a homogeneous country. And for some countries like China and India, such variance is too amazing to be captured in any national level parametric study. So we must caution the readers to take care of such limitations while drawing any straightforward conclusions from such aggregative studies. What we can reach at best is some indications across the countries. What is more, every country has its own trajectory of economic development. So any vertical comparison may lead to unwarranted outcomes. On the other hand, individual country level farm management data should be incorporated while studying agricultural sustainability, which are not readily available. So, more micro level study is necessary before drawing any conclusion.

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