World Journal of Science, Technology and Sustainable Development, Vol. 7, No. 2, 2010

SUSTAINABLE KNOWLEDGE FOR SUSTAINABLE DEVELOPMENT: CHALLENGES AND OPPORTUNITIES FOR AFRICAN DEVELOPMENT

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Abstract: Sustainable development is becoming increasingly a major concern for African Countries. They need a relatively high rate of growth of GDP to solve the many problems of poverty and underdevelopment, while insuring sustainability to their economies. At the same time, it is increasingly recognised that sustainability requires more and more knowledge assets and capabilities. This paper aims at showing the difficulty in attaining sustainable development for African countries with a weak technological and knowledge base. It deals first with the issue of knowledge systems and knowledge economy and their links with sustainability from a conceptual point of view. It highlights the specific situation of African countries stressing the difficulties they meet in this respect in a second section. This paper then shows how knowledge capabilities are highly correlated with levels of sustainability using knowledge and sustainability indexes. The discussion addresses technology transfer and innovation as key elements of knowledge, while the conclusion explores some of the opportunities.

Keywords: sustainable development; knowledge systems; knowledge economy; innovation; sustainable knowledge.

INTRODUCTION

Sustainable development is becoming increasingly a major concern for world development since the Rio Summit in 1992 and one of the major challenges on the international agenda in the face of worsening indicators of most resource-use and worsening environmental impact. The 1987 Brundtland Report, of the World Commission on Environment and Development (WCED, 1987) defined sustainable development as "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The new regulatory principle, 'pollution prevention pays', aims at promoting competitive and environmentally sustainable industrial production. While many of the work and resolutions are centred on costs and pricing both in terms of understanding and as a policy instruments, it is only in the last few years that Science and Technological (S&T) capabilities issues are brought in front of the scene. It is gradually recognised that Sustainability relies more and more on innovation capabilities and on harnessing the necessary knowledge.

In Less Developed Countries (LDCs), the situation is more challenging: while GDP

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growth of 6% to 8% per year is needed in the next three or four decades to grow to meet all their needs, they have to comply with sustainability requirements while developing the necessary knowledge assets and capabilities, they often lack. The transition to a global, networked knowledge economy will be one of the most important social and economic changes of the next decades. Knowledge is known, to be sometimes of difficult access and its price is distorted by world market, under intellectual property rights and other restrictive practices which do not benefit LDCs. This is the case for African countries where the level of innovation performances remains dismal and where major investments made in education, training and research have yielded only minor results. This situation raises two fundamental questions. The first one relates to the opportunity of insuring sustainability of growth while competitive pressures drive these countries to maximum use of natural resources, over-crowding of cities, and the acquisition of packaged, ready to use technology, produced elsewhere. The second one relates to the relatively weak knowledge base and the difficult integration of knowledge economy approach in most economic policy agendas (Djeflat, 2006b). We will argue, in this paper, that sustainability of growth rests fundamentally on the capability of properly harnessing knowledge. In other words, 'sustainable knowledge' remains paramount to sustainable development. This raises important theoretical and conceptual issues on the linkages between sustainability of development and knowledge. From an empirical point of view, we will try to analyse the difficulties met in the process of putting knowledge to work for sustainability while stressing some of the new opportunities. In this endeavour, we will look, in a first section, at the relationship between knowledge systems, knowledge economy and sustainability from a conceptual and theoretical point of view. The second section will raise the issue in relation to African countries with the objective of highlighting the effects of low knowledge base on sustainability. A third section will examine from an empirical point of view this relationship and its measurement, using data from both advanced and African countries.

SUSTAINABLE KNOWLEDGE FOR SUSTAINABLE DEVELOPMENT: CONCEPTS AND ISSUES

There is an increasing belief that Science, Technology and knowledge play an important role in sustainable development (Dayan, 2005). Consequently knowledge systems and knowledge economy seem to open up new and varied avenues to be explored in the direction of sustainability. How can knowledge enhance sustainable development? This is the main issue we will address in this section

Knowledge systems and sustainable development

In an organised economy, according to the loops of reusing resources and the quality of information, development and efficiency are not dependant anymore on salaries and large scale of production. The critical resources become practical knowledge, local entrepreneurial dynamism and trust, cooperation over the fence among organisations, human intelligence and know-how. This leads to an 'economy of human intelligence' (Dayan, 2005). Knowledge can make substantial and essential, contributions to sustainability across a wide range of places and problems (International Council for Science, 2002). Unless that contribution can be dramatically increased, however, it seems unlikely that the transition to sustainability will be either fast or far enough to prevent significant degradation of human life and the earth system (National Research Council, 1999).

Table 1 The knowledge dilemmas and effects on sustainability

High potential for sustainability	*Low potential for sustainability*
Evolutionary perspective	Neo-classical perspective
Public	Private
Non-rival	Competitive
Codified knowledge	Tacit knowledge
Cumulative	Obsolescence
Externalities	Protection
Collective learning	Expertise
Diffusion	Intellectual property rights
Public policies	Market
Long life learning	Specialisation

Source: Djeflat (2006).

To achieve that level of contribution, several conditions need to be fulfiled. They relate to the specific nature of knowledge, to successful combination of material and knowledge assets and to the type of knowledge system.

Firstly, regarding the specific nature of knowledge, it obeys public goods rational and evolutionary principles on one hand and market rules in a neo classical framework, on the other (Djeflat, 2006b). Integrating knowledge and sustainability requires often a mix of the two in a pragmatic way. It is clear from Table 1 that sustainability is easily reached when knowledge is public, non-rival, codified and source of high externalities. It can thus be more easily circulated and shared amongst various actors. Its potential for sustainability is reduced if it is privately owned, subject to market rules and fierce competition, highly protected, tacit, specialised and under the constant threat of obsolescence.

Secondly, as a result of ever increasing proportion of knowledge in the production of goods and services, more and more emphasis is put on knowledge assets as source of wealth creation. However, these kinds of assets may not be easily grasped when it comes to sustainability. Several studies reveal that sustainability can be more easily achieved when material assets are efficiently combined with knowledge assets. Industrial ecology, for example has already explored avenues for combining efficiently material and knowledge assets. Knowledge management is one of the key elements in this process (Dayan, 2005).

Thirdly, it became more and more evident that sustainability depends on developing integrated knowledge systems, a lesson already learned in the agriculture, defence and health sectors (Cash et al., 2003). Knowledge system approach appears to give knowledge more effectiveness in harnessing S&T with the goals of sustainable development. A Knowledge system is viewed as consisting of a network of linked actors, stakeholders, organisations and objects that perform a number of knowledge-related functions (including research, innovation, development, demonstration, deployment and adoption) that link knowledge and know-how with action. Included are also incentives, financial resources, institutions and human capital that give such a system capacity to do its work. Bearing in mind that usable knowledge is ultimately 'contextualised', that is, adapted to specific circumstances or places, several issues can be raised: they relate to the generalisation of the effective knowledge systems to various places, sectors and problems including governing knowledge systems (Matson, 2007), to the kind of knowledge which needs to be mobilised (formal, clinical or tacit knowledge), to the mix of knowledge to be used and to pricing. Recent contributions have developed a critical review of controversial economic theories of pricing natural capital and knowledge capital that affect prices (Nguyen, 2006). Finally, they relate to the balance between intangible capital and material resources. The importance of the intangible resources in sustainability is increasing. While production and growth are material-centred, sustainability appears to rest more on intangible assets used to exploit material resources. A development strategy that focuses only on production capital and neglects intellectual capital is therefore not sustainable. However, society lacks a critical understanding of what kind of programs, institutional arrangements, and, more generally, knowledge systems can most effectively help harnessing S&T for sustainability (Cash et al., 2003). Knowledge economy approach appears to give a more accessible and easily understandable relationship between sustainability and integrated approach of knowledge.

Knowledge economy and sustainability

Knowledge system paradigm is usually put in the framework of knowledge economy. It could be defined as "the economy in which knowledge is the key resource and in which the generation and exploitation of knowledge have come to play a predominant part in the creation of wealth" (Department of Trade and Industry, 1998). The knowledge economy framework (Dahlman, 2003) uses a systemic approach of four pillars (innovation, education, ICTs and institutional framework) which shows how knowledge is created, circulated, valorised and governed for the purpose of economic development and growth (Aubert and Reiffers, 2003). In an earlier work (Djeflat, 2006a) we addressed several issues related to the relationships between knowledge economy and innovation systems. This section will look at the new opportunities for sustainability that knowledge economy offers. The knowledge economy paradigm suggests that physical resources can be almost infinitely stretched through the 'substitution' of physical resources by information, knowledge and immaterial resources, giving thus new prospects for sustainability. Examining closely each one of the components, gives deeper insight into this relationship.

Firstly, ICTs have brought tremendous potential for sustainability and environment protection and several contributions have listed the countless possibilities which they bring: (learning, data base collection and storage, diffusion of vital information, data generating systems, monitoring and control of environments, etc.). Recent studies illustrate ICT's potential for sustainability (Mansell and When, 2005). In Indonesia, for example, a programme initiated by the Forestry Ministry to aid in sustainable forestry management involved identifying and coding of trees, optimising forest maintenance and training in the use of laptop computers using specialised software (Talero and Gaudette 1995). Other techniques include computer-aided, scientifically applied, modelling techniques, networking and information exchange. Several international organisations and institutions have built all their environment and sustainable development programmes on ICTs. For example, UNDP built a Sustainable Development Networking Project. This is a specialised online system for scientific, technical, bibliographic and institutional sources. The network currently consists of 173 national, government designated focal points that are collaborating with the UNDP. Other important issues include the inter-generational transfer of masses of information and know-how in the era of internet (Ermine, 2008; Vachon, 2008).

Secondly, innovation is a key element in sustainability. In the drive to highlight the fundamentals of sustainability, many

Table 2 The various spheres and actors involved in environment protection and sustainable development innovation systems

Research sphere	*Industry sphere*	*Government sphere*	*Donors sphere*	*Social acceptance*	*International organisations*
University-university	Industry-industry	Compliance R&D support	Donors-government In LDCs	Civil society	Setting International regulation
University industry	Industry market	Prevention of resources-diversion	Donors-NGOs	NGOs	Diffusion of standards and best practices
University research centres	Industry-university	Innovation diffusion within national boundaries	Donors civil society	Press and Media	Incentive system
University-industry-research centres	Industry-Government	Innovation Diffusion abroad			
		Training of regulators			

Sources: Drawn from Warhurst.

scholars have concentrated on cost and benefit, the two key elements in decision-making for environment protection (Tilton, 1992; Warhurst, 1998). This approach in terms of cost/benefits however fails to integrate the technology factor. From an empirical point of view, studies conducted in the mining sector have shown that environmental degradation is greatest in operations working with obsolete technology. Firms that pollute the most are mismanaging the environment precisely because of their inability to innovate and the most efficient firms are generally better environmentally managed, because they are innovators (Warhurst, 1998). Examples throughout the literature show that innovation can reduce pollution, and that firms that adopt this strategy build competitive advantages as well as environmental benefits. In the mining sector, environmental performance of an enterprise is more closely related to its innovative capacity than to the regulatory regime under which it operates (Acero, 1993; Lagos, 1992). Companies adapt to environmental regulatory pressures by innovating, improving and commercialising their environmental technology and environmental-management practices, at home and abroad. New and more stringent noise pollution regulations in the 1970s saw the emergence of a host a new products and services for noise control in Great Britain and some Scandinavian countries, including from the polluters themselves (Djeflat, 1975). On more global terms, technical innovation, for instance in terms of developing substitutes to naturally scarce raw products, may help to overcome the fact that natural capital cannot always be reproduced (Johnson and Lundvall, 2000). However, pollution control and environment protection are only one of the objectives of sustainable development. Sustainability is also about reducing poverty, education, health and welfare and rural development. Finally, innovation requires that innovative capabilities are transferred to future generations on top of the fact that some results of fundamental research may be stored to meet future needs (Table 2).

Thirdly, while education and training need to be singled out, when raising the issue of sustainable development, they need to be singled out, when raising the issue of sustainable development, due to their importance in the production of appropriate knowledge but also in its diffusion and renewal. As stated in the world summit for sustainable development, young adults tend to emerge from the educational system without a deep sense of ecological matters and without knowing what to do with the knowledge they have. They are unequipped to make decisions that are environmentally enlightened when they take their place in the work force (International Environment Forum, 2002). The new education paradigm should therefore foster different values and attitudes such as cooperation instead of competition. Such an educational approach would be participatory, interactive, integrative, value-driven and knowledge-based that is, that it encourages creativity, innovative attitude and the constant drive to renew its stock of knowledge. Knowledge is under the permanent threat of being obsolete and requires learning permanently through academia and interactive life long learning.

Finally, one of the key questions is how institutions can play an adequate role and give the necessary atmosphere to mobilise knowledge for sustainable growth and development. This issue raises another question related to the private sector involvement, both as user and as a source of relevant knowledge for sustainability (Hardi, 2000). It involves also all the other issues addressed usually by public economics of free-riding, prisoner's dilemma, aligning incentives and the distribution of authority applied to knowledge (Olson, 1971). Policy aims generally at integrating sustainable development as a guiding principle in all government actions in order to ensure that economic and social development keep within ecological limits, particularly in the area of S&T policy, where there is a lack of incentives to set strong priorities for promoting sustainable development.

KNOWLEDGE AND SUSTAINABILITY IN AN AFRICAN CONTEXT

The issue of knowledge and sustainability in African countries, in particular, raises several questions, as a result a weak knowledge base, incomplete innovation system and often weak sensitivity to sustainable development gains. As remarked elsewhere, these issues may seem as luxury in a continent were poverty, hunger, illnesses, disease and conflicts prevail (Johnson and Lundvall, 2000). However, one cannot help relate the issues of African development to that of sustainability based on knowledge, where current endogenous capabilities are weakened by limited access to advanced technology and its difficult transfer. Yet when examining the linkages between knowledge and sustainability, it becomes clear that new opportunities exist for African development. We will examine, in this section, what these difficulties are and what new opportunities exist.

Knowledge systems and sustainability raise specific issues from a developing country perspective, in our view. The relatively weak knowledge base and the difficult integration of knowledge economy in most economic policy agendas are more than obvious. In an earlier work we have highlighted some of the impediments (Djeflat, 2006b). While the impact on the local industry can be quite substantial in terms of employment creation, outsourcing to local industry with the effect of upgrading their facilities and know-how, and perhaps in some cases, trigger a real innovation dynamics, examples and success stories to substantiate that, are still relatively limited and particularly when it comes to African countries, with the exception of South Africa.

It is recognised in recent contributions, that building more effective knowledge systems for sustainability takes time and patience (Cash et al., 2003). Strategies to promote such systems require a sufficiently long-term perspective that takes into account the generally slow impact of ideas on practices, the need to learn from field experience, and the time scale involved in enhancing human and institutional capital necessary for doing all these things. A decade or more thus seems the minimal period over which efforts are deployed to harness S&T for sustainability (International Council for Science, 2002; Lubchenco, 1998; Unesco, 2000). In many African countries, pressure for development, coupled often with the need to face global competition, leave very little scope and room for manoeuvre for decision-makers to start off this long-maturing process. ICTs, while making remarkable progress in recent years, are very much in the realm of digital divide and again more demand and less supply oriented. Education and training as a means of knowledge diffusion and competence building face major obstacles. As seen earlier, knowledge which is vital to sustainability sees its price distorted in the face of high intellectual property barriers. Institutions are mismanaged and governance appears to be a common concern for the majority.

While stressing all these difficulties in harnessing knowledge systems, there are several opportunities which the adoption of the knowledge economy approach opens up for African countries in terms of sustainable development. ICTs give new opportunities for taping into global knowledge for African countries and improving their relatively week local knowledge base. They also give them the opportunity to extend their knowledge system to include their diasporas as shown by success stories in India, China and South Korea. They finally give the opportunity for local firms and research institutions to integrate knowledge networks and update their often obsolete tools and methodologies. New opportunities offered by e-learning can help reinforce the often weak education and training system. Paradoxically, while the much publicised digital divide is a real issue for African countries and indeed raises the threat of these countries being left behind, the ‘knowledge divide’ is rarely put forward as another possible risk enhancing what we could call the ‘sustainability divide’ which is gradually taking place. Improving the knowledge base of African countries will, therefore, lead to higher potential for sustainability as we have hypothesised and we will try to substantiate in the next section.

MEASURING THE LINK BETWEEN KNOWLEDGE AND SUSTAINABILITY

From an empirical point of view, knowledge systems appear to be closely related to sustainability. Two indicators have been selected to show this relationship: the Knowledge Index (KI) and the sustainability index.

The knowledge index

As explained earlier, the knowledge economy builds on indicators and variables: the two main parameters are the Knowledge Economy Index (KEI) and the KI. The KI, which appears more appropriate and for which data are available for a sufficient number of countries, measures the ability to generate, adopt and diffuse knowledge. It constitutes an indication of overall potential of knowledge development in a given country and is defined by the World Bank Institute as “the average of the normalized performance scores of a country or region on the key variables in three indicators: education and human resources, innovation system and information and communication technologies” (Dahlman, 2003). The three indicators include several variables related to knowledge generation and knowledge diffusion as shown

Table 3 The KEI and variables

Indicators	*Variables*
Knowledge index	
Education and human resources	– Adult literacy rate
	– Secondary enrolment
	– Tertiary enrolment
Innovation system	– Royalty and license fees payments and receipts
	– Patents applications granted by the US Patent and Trademark Office (USPTO)
	– Scientific and technical journal articles
Information and communication technology	– Telephone per 1000 people
	– Computers per 1000 people
	– Internet Users per 10,000 people
Knowledge Economy Index (Add)	
Institutional framework and governance	

Source: World Bank Institute 2008.

in Table 3. The fourth indicator which relates specifically to the KEI reflects the institutional dimension and has moved gradually in recent years to reflect more and more the business climate. This is the reason we have not taken it into account here.

The normalisation procedure brings all the indicators to the same standard of measurement through the process known as normalisation through the next formula:

$$N(u) = 10\left(\frac{1 - Nh}{Nc}\right)$$

where N(u) represents the normalised score of an index, Nh represents the number of countries with high rank and Nc the total number of countries in the sample with available data.

The environmental sustainable index and environmental performance index

The two main indexes used are the Environmental Sustainable Index (ESI) and the Environmental Performance Index (EPI). The ESI provides a gauge of a country's long-term environment trajectory. Constructed around the concept of sustainability, it tracks the environment past, present and future. In contrast, the EPI addresses the need for a gauge of policy performance in reducing environmental stresses on human health and promoting ecosystem vitality and sound natural resources management (Yale Centre for Environmental Law & Policy and Centre for International Earth Science Information Network, 2005). The ESI score represents an equally weighted average of the 21 indicator scores (Table 4). Each indicator builds on between 2 and 12 data sets for a total of 76 underlying variables. The 21 indicators are grouped into 5 components: environmental systems, reducing environmental stress, reducing environmental vulnerability, social and institutional capacity and Global stewardship.

Of all the components, the 'social and institutional capacity' appears to be more related to our problematic. The four components relate to knowledge dimension

Table 4 The Environmental Sustainability Index (ESI)

Indicators	*Indicators*
– Air quality	– Reducing environment-related natural disaster vulnerability
– Biodiversity	– Social and institutional capacity
– Land	– Environmental governance
– Water quality	– Eco-efficiency
– Reducing air pollution	– Private sector responsiveness
– Reducing ecosystem stress	– Science and technology
– Reducing population pressure	– Participation in international collaborative efforts
– Reducing waste and consumption pressures	– Greenhouse gas emissions
– Reducing water stress	– Reducing transboundary environmental pressures
– Natural resources management	
– Environmental health	
– Basic human sustainability	

Source: The "2005 Environmental Sustainability Index" report.

either directly or indirectly: the first indicator 'Environmental governance' includes the knowledge creation in environmental science, technology and policy variable, stressing thus the need for knowledge in sustainability. The 'Science and technology' indicator includes also direct measurement of knowledge: namely innovation index, digital access index, female primary education completion rate, gross tertiary enrolment rate, number of researchers per million inhabitants and world economic forum survey on private sector environmental innovation. On top of these direct knowledge variables, many of the others can be considered as indirect measures of knowledge for example, Government effectiveness or Number of ISO 14001 certified companies per billion dollars GDP (PPP).

The EPI builds on two broad environmental protection objectives:

1 reducing environmental stresses on human health
2 promoting ecosystem vitality and sound natural resource management.

Environmental health and ecosystem vitality are gauged using 25 indicators tracked in six policy categories: environmental health, air pollution (effects on ecosystems), water (effects on ecosystems), productive natural resources, biodiversity and habitat and climate change. The EPI utilises a proximity-to-target methodology focused on a core set of environmental outcomes linked to policy goals. The 2008 EPI includes 149 countries based on data availability (Yale Center for Environmental Law & Policy & Policy Centre for International Earth Science Information Network, 2008).

The EPI has since 2005 replaced the ESI for a variety of reasons explained by the authors (Yale Centre for Environmental Law & Policy & Policy Centre for International Earth Science Information Network, 2006).

The empirical analysis was conducted on two samples of countries: the first 15 countries in the world in terms of ESI which are then compared to the 17 African countries for which complete sets of data for ESI, EPI

Table 5 ESI and KI in the first 15 countries in the world in terms of ESI (option a)

Rank	*Country*	*ESI 2005*	*KI 2008*
1	Finland	76.1	9.34
2	Norway	73.4	9.30
3	Uruguay	71.8	6.28
4	Sweden	71.7	9.69
5	Iceland	70.8	8.90
6	Canada	64.4	9.05
7	Switzerland	63.7	9.00
8	Guyana	62.0	4.50
9	Argentina	62.7	6.39
10	Austria	62.7	8.77
11	Brazil	62.2	5.90
12	Australia	61.0	9.23
13	New Zealand	60.9	9.00
14	Latvia	60.4	7.47
15	Peru	60.4	4.66

Source: World Bank Institute 2008 and Report "Pilot 2006 Environmental Performance Index".

and KI are available. The non-availability of published data made it difficult to include all African countries. Both least square and correlation coefficient methods are used to have complementary and more robust results.

ESI and KI

The latest data found for ESI are from 2005 while KI data are from 2008. A first glance (Table 5) shows that 9 out of the first 15 countries in ESI are from advanced countries in terms of environmental sustainability. Nonetheless six countries are from the developing world, half of them from Latino-America. This is an indication that sustainability may not be directly related to the level of development, which is also the conclusion that the World sustainability report found. The relatively high score can be related to certain indicators found in the ESI matrix. These include air quality, biodiversity, land and greenhouse gas emissions. This argument needs to be put in relative terms though. In terms of knowledge, the figures indicate that the first countries in the world have also relatively high to medium KI (above five) with the exception of two countries: Guyana and Peru.

When looking at the first 15 countries in the world in terms of KI, half of them score less than 60 in terms of ESI (2005). Only four can be considered to have high scores: Iceland, Sweden, Finland and Norway (Table 6).

Data in Table 7 indicate that African countries which score relatively low in KI are also ranked in low positions in the ESI. Here also, some remarks can be made. Some countries which are least developed countries in the world seem to have relatively higher ESI than North African countries and which are much wealthier countries: this is the case of Mali and Madagascar. On the other hand, North African countries which score higher on the KI are not the

Table 6 ESI and KI (option b)

	ESI 2005	*KI 2008*
Denmark	58.2	9.56
Sweden	71.7	9.69
Finland	75.1	9.34
Netherlands	53.7	9.34
Norway	73.4	9.30
Canada	64.4	9.05
Switzerland	63.7	9.00
USA	52.9	9.09
Australia	52.9	9.23
Germany	56.9	9.01
UK	50.2	8.81
Iceland	87.6	8.90
Austria	62.7	8.77
Ireland	59.2	8.79

Source: World Bank Institute 2008 and "Pilot 2006 Environmental Performance Index" Report.

Table 7 ESI and KI in African countries

	ESI 2005	*KI 2008*
Algeria	46.0	3.42
Tunisia	51.8	4.50
Morroco	44.8	3.26
Malawi	49.3	0.90*
Ethiopia	37.9	0.89
Benin	47.5	1.59
Sudan	35.9	1.46*
Rwanda	44.8	0.83
Madagascar	50.2	0.53*
Mali	53.7	1.02
Sierra Leone	43.4	0.84
Nigeria	56.2**	1.99
Zambia	51.1	1.34*
Mozambique	44.8	0.98
Burkina Faso	45.7	0.99
Mauritania	42.6	1.47
Angola	42.9	1.43

*The KEI is used in this case as a good proxy of the KI because of the missing figures for this latter.
**The EPI score is used as good proxy of ESI because of the missing data.
Source: World Bank Institute 2008 and "Pilot 2006 Environmental Performance Index".

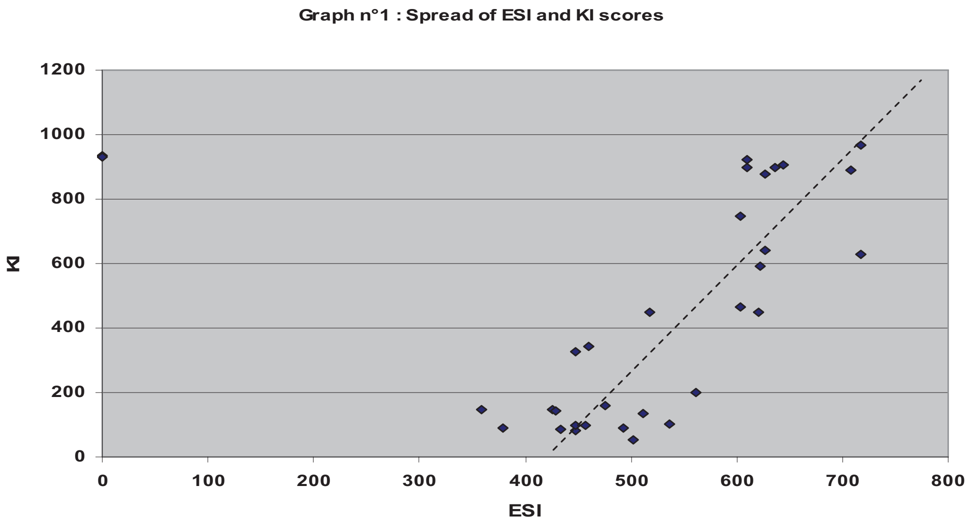

Figure 1 Spread of ESI and KI scores

best in terms of ESI with the exception of Tunisia. This is partly due to the fact that these countries have some industrial base and infrastructure which are contributing to the degradation of the environment: oil, steel and petrochemicals in Algeria and phosphates in Morocco and Tunisia.

Figure 1 shows that advanced countries tend to concentrate in the top of the first half of the graph, while African countries are in the bottom with a clear cut off line in the middle. The strength of the relationship is shown by the relatively high score of the correlation coefficient which is $R^2 = 0.75209$ (option a) and $R^2 = 0.8620$ (option b). However, when taking African countries separately, the coefficients are much lower. This is an indication that other factors matter are at play such as governance and financial capital.

EPI and KI

The EPI scores of 2008 make it more appropriate to cross with the 2008 KI index. Table 8 shows that the first 15 countries in the world on the knowledge grid score reasonably high on the EPI 2008 grid.

They all score higher than 80 with the exception of the Netherlands and Australia. African countries which score relatively low in KI are also ranked in low positions in the EPI. However there is a clear distinction between Sub-Saharan and North African countries. These latter seem have higher EPI scores: Tunisia's score for example is almost equal to that of the Netherlands even though its KI is 50% less. This is partly due to the fact that these countries have made a significant progress in environment protection in recent years, particularly from the institutional point of view, but slower progress in knowledge, namely as a result of poor innovative activities (Djeflat, 2006) (Table 9).

This is clearly shown by Figure 2. Advanced countries tend to concentrate in the top right of the first half of the graph, while African countries are in the bottom left part with a clear cut off line in the middle. We can also notice that North African Countries are clearly detached from the rest of African Countries and constitute a cluster on their own. In both cases, the least square line indicate a relatively strong relationship which is reflected through

Table 8 EPI and KI 2008 in most advanced countries

	EPI 2008	*KEI 2008*	*KI 2008*
Denmark	84.0	9.58	9.56
Sweden	93.1	9.56	9.69
Finland	91.4	9.37	9.34
Netherlands	78.7	9.30	9.34
Norway	93.1	9.29	9.30
Canada	86.6	9.14	9.05
Switzerland	95.5	9.13	9.00
USA	81.0	9.10	9.09
Australia	79.8	9.09	9.23
Germany	86.3	9.01	9.01
UK	86.3	8.92	8.81
Iceland	87.6	8.90	8.90
Austria	88.9	8.90	8.77
Ireland	82.7	8.90	8.79

Source: World Bank Institute 2008 and Report "2008 Environmental Performance Index".

Table 9 EPI and KI in African countries

Countries	*EPI 2008*	*KI 2008*
Algeria	77.0	3.42
Tunisia	78.1	4.50
Morroco	72.1	3.26
Malawi	49.3	0.90*
Ethiopia	56.1	0.89
Benin	55.5	1.59
Sudan	54.9	1.46*
Rwanda	54.6	0.83
Madagascar	51.3	0.53*
Mali	40.0	1.02
Sierra Leone	39.1	0.84
Nigeria	56.0	1.99
Zambia	54.7	1.34*
Mozambique	50.5	0.98
Burkina Faso	44.2	0.99
Mauritania	39.5	1.47
Angola	42.9	1.43

Source: World Bank Institute 2008 and "2008 Environmental Performance Index" Report.

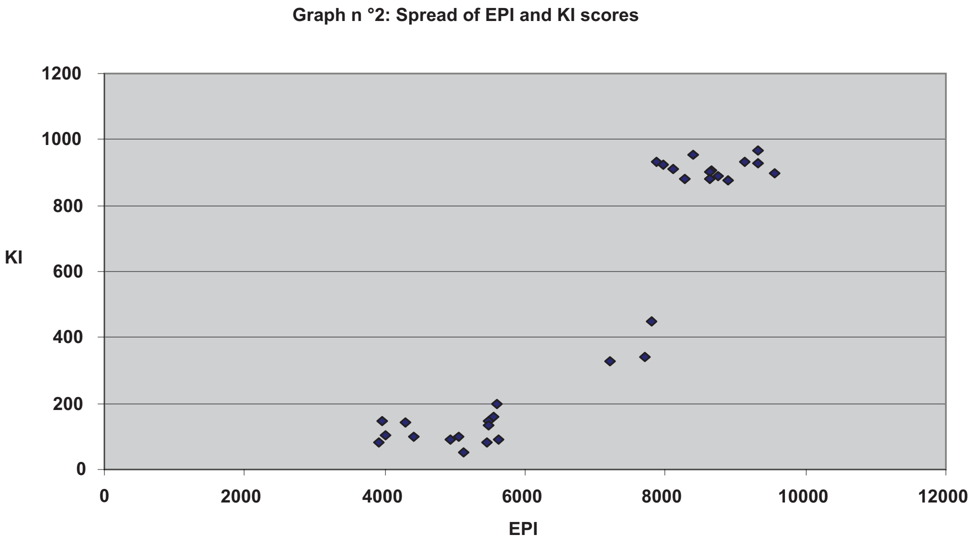

Figure 2 Spread of ESI and KI scores

the relatively high coefficient correlation $R^2 = 0.9296$ and $R^2 = 0.8402$ for African Countries taken separately. This is an indication that in the case of African countries, knowledge counts a great deal for sustainability. Further research is needed to shed more light on these issues.

DISCUSSION

Knowledge systems are thus closely correlated with sustainability both in Developed and in Developing countries. And indeed, the weak position of African countries in the sustainability grid is partly the result of their difficult access to knowledge with all its components. One of the key elements of this difficulty is the issue of technology transfer, the second one is the innovation issue which is closely related.

Firstly, technology transfer has always been an issue of concern for African countries who have remained for decades, permanently dependant on their technology suppliers (Djeflat, 1988). Under competitive pressure and market rules, technology suppliers have no incentive to transfer technology to recipients. However, in the area of environment protection, there are grounds, according to several scholars (Warhurst, 1998), for a 'new type of technology transfer' to take place in environmental management. It includes the knowledge, expertise and experience required to manage technical change, the development of human resources to improve overall production and energy efficiency and environmental management of plants and facilities. It emphasises training and skills acquisition, the novelty being the emphasis put on training and skill acquisition in environmental R&D. Technology transfer and technology partnership through joint ventures or strategic alliances are ways to build up these technological and managerial capabilities (Djeflat, 1996; Warhurst, 1998). However, evidence from the field tends to suggest that this process has some limitations. Examples from the mining sector show that international firms transfer significant amounts of managerial and engineering expertise through joint ventures and other collaborative arrangements but limited to the specific project. Yet, these contributions can be considerably increased without adversely affecting the supplier's strategic control of its proprietary technology (Auty and Warhurst, 1993; Bell, 1990; Warhurst, 1991a,b). Donors and international organisation can sometimes help suppliers to transfer their technology: they usually cover the costs of such operations. One of the programmes of Agenda 21, for example, encourages self-regulation, environmental R&D, worldwide corporate standards, and partnership schemes to improve access to clean technology world wide. However, for this transfer to be effective, a substantial increase in the technological capabilities of recipient countries is required (Barnett, 1993). This new concept mostly examined in a Latino American context does not seem however to be easily generalised to African countries where the mining sector is relatively important as a foreign currency earner and where it is almost fully dominated by technology suppliers.

Secondly, innovation is to be put against 'most pressing needs' issue. Pressing needs include of course hunger, poverty, protecting the earth life support system and biodiversity. Two questions can be raised: the first one is what drives African countries to innovate for sustainability if ever? The second questions is what S&T capabilities could they mobilise? There are several motives for African countries to innovate for sustainability: firstly, because upstream, they suffer from resources limitation which requires using them in a very parsimonious way not to have to undergo heavy environmental costs they could not bear and to guarantee to future generation access to a certain amount of these resources. Secondly, they need to innovate because of the many problems they are suffering from and which conventional techniques and approaches have proved difficult to resolve. Innovation has to be in all fields and not simply in the technical field: in the social, the political and the organisational fields. While all this drive to innovate exists, there are several impediments and we have highlighted some of these looking, specifically at Middle East and North Africa (MENA) countries in previous contributions (Djeflat, 2000). The most important impediments include the cost to the environment which does not seem to be strong enough to have a significant impact and which is usually externalised at firm level and does not constitute a strong motive to undertake innovative activities in this sense. This situation is found in the mining sector in Latino America (Warhurst, 1998) and can easily be found in the oil sector (Algeria, Nigeria) in copper mines (Zambia) in the phosphate industry (Morocco) (El Khabli, 2001). The second one is the force of regulations which normally should be a driving motive and which, in an African context, knows several obstacles dues to governance problems and the wide spread of corruption in the judicial system in particular. The third motive relates to social pressure which is relatively weak, the communities and villages most affected by pollution, environment hazards and non-sustainable behaviour have very little voice at the political level to express concern and put pressure on polluters to undertake technical or organisational innovation. Examples from the oil sector in Algeria show that major oil companies started changing their attitude and being more concerned with pollution control and environment protection only when, their key technical personnel started exercising pressure when they felt personally at risk. Pressure could not come from villages and populations living in the affected areas as a result of flared gas and severe air pollution. The fourth one is pressure from international organisations. This factor seems, in the current situation the most plausible factor and which can have a significant impact on Government and firms to change their technologies and organisation to more responsible behaviour. However, the limited financial means of already debt ridden African states make it difficult to divert precious resources to innovation, while other urgent needs are not satisfied. Moreover, it may have a counter-productive effect, and lead to a drawback in sustainability as a result of less investment for poverty reduction, health protection and education promotion. International public funding could play an important role in this respect. Credit conditionality could help enterprises change their technolological and environmental behaviour (Warhurst, 1998). The fifth one is related to the support coming from donor organisations, with has had some non-negligible impact in recent years. This was the case in the agricultural sector where some progress has been made using local competences in R&D to find local solutions to problems such as crop disease, water treatment or water-saving irrigation techniques. However, these success stories are far too limited, not sufficiently publicised and far too concentrated in agriculture and less in the industrial sector.

CONCLUDING REMARKS

We have highlighted above some of the fundamental issues and obstacles in the face of using knowledge for sustainability. Both the conceptual and the empirical analyses have shown that knowledge systems and sustainability are closely inter-linked and relatively highly correlated. This stresses our hypothesis that knowledge and technology transfer remain paramount to sustainable development in Developing countries as a whole and African countries in particular. However knowledge systems and sustainability are on different time scales and face different kinds of imperatives. While the building of knowledge is a long-time scale, some of the sustainability issues are on a much shorter time scale. For this latter type of issues, there are prospects and opportunities which Africa could seize. We will list them briefly here. The first opportunity is the new drive in the industrial fields for more ethical conduct, equitable trade and common destiny which is rapidly expanding in advanced countries. The social responsibility of enterprises appears a common concern for industrial firms throughout the world. New investment projects increasingly incorporate economic and environmental efficiencies into the production process, not just through new plants or equipment but also through improved management and organisational practices. The second opportunity is the New Partnership for African Development (NEPAD) programme which has set S&T as a priority and a tool to fulfil the immediate needs of the continent such as poverty elimination, improvements in public health, access to safe drinking water and environmental protection. It is encouraging both a dialogue between stakeholders in S&T and the elaboration of an appropriate regulatory and policy environment to nurture private investment in R&D. The third opportunity is the prospects offered by indigenous knowledge: What is missing in the capability based approach, as well as more generally a focus on learning capabilities as a whole. Many different kinds of learning are going on in society, that is, in rural areas, villages, firms and organisations in the public sector as well as the private. Yet, only a part of this takes place in the formal education system or in the research system. What needs to be understood is how and to which extent individuals, communities, firms and organisations are geared to learning and innovation, either by themselves or in interaction with others (Jonhson and Lundvall, 2000). The recognition of local and indigenous knowledge systems creates opportunities for establishing sustainable development and natural resource management processes that are rooted in social equity and relevance, local ownership and value systems, sound institutional partnerships and the valuation of both cultural and biological diversity. Another reason is that the need and opportunity to build on local and traditional knowledge may be relatively bigger in the South than in the North. The existence, character and usefulness of this knowledge may not be well known to national and international firms and policy makers. It is therefore vital to underline the importance of tacit knowledge and to draw attention to the need not to loose large parts of mostly not codified and undocumented local competencies. All these avenues are promising for African sustainable development through sustainable knowledge. They need to be further investigated.

BIOGRAPHY

Abdelkader Djeflat received a PhD in Industrial Management at the University of Bath-UK (1982). Formerly, Full-Professor of Economics at the University of Oran in Algeria, he teaches currently at the Faculty of Economics of the University of Lille I (France). He has several books and papers on the issues of science and technology for development. He is also the founder and current chairman of the MAGHTECH (Maghreb Technology) Network (http://www.fraternet.org/maghtech).

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