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Theories of technology generation

- 1 There is a large literature on technology generation, and there are many ways of characterising the main debates. For present purposes it will be convenient to distinguish between two broad sets of approaches : those of the "splitters" and those of the "lumpers".
- 2 Splitters view technology and social action as separate fields. Learning new ways of manipulating the physical materials of life is (or can be) a-social (how we acquire knowledge of the composition of matter, although social activity, does not in the end affect the content of that knowledge). This position may make better sense for "pure" science (cf. Wolpert 1992) than for "applied" fields. Whatever the case, technology (at least for the sake of argument) is viewed as an exogenous variable from a sociological point of view. The questions asked by splitters include : "how do material processes work ?", and "what impact does technology have on society ?".
- 3 Lumpers are transfixed by the idea that there is no hammer without a hand, and that the hand is under social control (e.g. through the social organization of labour). To split off technology from its social moorings, even if only as an analytical conceit, is intellectually dangerous since it creates the illusion that technology could cause social change, instead of being an integral element within that process. Lumpers create and use terminological schemes that remind us that we are required to address a reality made up not of "society" and "technology" as separate spheres, but of socio-technological complexes. Latour's (1993) emphasis on "hybridity" (the

never-ending "interbreeding" - as it were - of social and technical elements in our lives) is probably as good a way as any of keeping the lumpers' central point-of-view in focus. A key question posed by lumpers concerns the climate for innovation - "what balance between managerial intervention and mechanical manipulation best sustains the generation of healthy (in the sense of good, as well as most-effective) technology?".

- 4 Lumpers and splitters inhabit all the main disciplinary branches of technology studies in the social sciences (economics, sociology, philosophy, politics, anthropology). By tradition engineering, and other practice-oriented disciplines, have been dominated by the standpoint of the splitters, but lumpers are increasingly conspicuous on the ground, especially in fields of technical practice applied to the problems of developing countries (a "school" of tropical irrigation engineers, based on the Agricultural University of the Netherlands, seems at times willing to characterise its work as "socio-engineering").
- 5 Within the social sciences there are two main analytical foci in technology generation/diffusion studies: political economy approaches and organizational/institutional approaches, with lumpers and splitters in both fields.
- 6 The well-established neo-classical (supply/demand) approach to technological innovation provides one of the best exemplifications of the splitters' approach. Supply and demand for new technology are treated as analytically discrete. Technological advance is "induced" by independent social forces manifest in the market place. This viewpoint is contested by neo-Marxists. Lumpers in regard to technology & society (unlike so-called "Vulgar Marxists" who, as techno-determinists, are splitters) Neo-Marxists consider the forces and relations of production to be inseparable; innovations and power elites are mutually determinative within a social formation. Society gets the technology its place in history warrants.
- 7 Diffusion/impact theorists (e.g. Rogers 1983) are splitters, since they start with technology as an a-social given, an exogenous variable, and then trace the impact of innovations as they spread through society, logging the changes wrought in, e.g. institutional values and organizational forms, as these adjust to the presence of a new technical element. The proponents of radical social constructivism (cf. Collins & Yearley, 1992) might be counted, equally, as splitters - but starting from the exactly opposite premise. Their ultimate reality is social reality; all scientific understandings and technical inventions are "products" of this social reality.
- 8 The organizational/sociological/lumpers follow one of at least three analytical tendencies: the Actor-Network approach (cf. Law & Callon 1992, Fujimura 1992), "cultural theory" (as expounded by, e.g., Douglas 1987), and, third, studies of the organization and management of technological research based on a broad commitment to the assumptions of methodological individualism.
- 9 Since we aim to show how studies of hybrid socio-technical ensembles might prove to be of practical significance to development agents charged with technology generation, we give a brief exposition of a few key features of each body of theory in the next section.

Theories of socio-technological hybrids Actor-network theory

- 10 In a paper on the design of a British fighter aircraft, Law and Callon (1992) show that before the plane even reached the drawing board it was the "product" of negotiation among politically-salient parties, and that these Actor-network negotiations

significantly "shaped" the endproduct. Law & Callon suggest, therefore, that to "map" the actor-networks that come together in any technology project is a significant step towards understanding the technical design process and its outcomes. This offers scope for what is termed "interpretive flexibility": design modification resulting from the tension between different actors, and their, at times, divergent sense of what is needed and what can be achieved.

- 11 Fujimura (1992), dealing with a scientific rather than technological example (the case of oncogene theory), links up artefact and actor-network theory the other way round, by suggesting that working alliances among scientists should be seen, in significant respects, as the product of apposite (or inept) choice of working concepts. Her study, however, offers no support to an extreme social constructivism in which choice of concepts is arbitrary in relation to physical reality. A concept such as the oncogene "works" only if it is sufficiently on-target to be a viable cognitive proposition when set up against biological reality. But to take off, scientifically, it also needs to provoke a social response - the formation of the right kind of working groups to bring about a concrete realization of the science necessary to clarify the concept. The oncogene, she suggests, exemplifies the notion of a "boundary object" - a distantly perceived reality that makes sense (even if only hazily) from the hitherto distinct perspectives of two or more disciplines, and so catalyses new collaborative social energies among scientific professionals.

Culture Theory

- 12 The culture theory school concentrates on the point that values implicit in technology development are, according to a cross-cultural reading of anthropological evidence relating to institutions, inseparable from social organization. In a classic study, Douglas & Wildavsky (1982) show that ideas about the intrinsic safety or riskiness of nuclear energy are embedded within the discrete institutional cultures of proponents and opponents. Civil servants, internalising the strongly hierarchical values of government bureaucracy, tend systematically to underestimate safety requirements, whereas nuclear protestors, much more likely to be creatures of an egalitarian-sectarian institutional culture, overestimate the same dangers.
- 13 The point the culture theory school stresses is that values are not separable from, or portable across, organizations. Culture-theory (so far) is oriented more to the understanding of value conflicts over modern technology, rather than to their resolution, but (seemingly) implies that real consensual technological progress, in future, may depend on the extent to which opponents agree to merge their differences in new hybrid social projects from which new institutional values might flow. Understanding of how, and under what conditions, social institutions hybridise is as yet very vague, but given the potential importance of the topic in a "globalizing" world, some hold out hope that a cognitively-grounded theory of "cultural creolization" may one day provide enlightenment in this area (cf. Hannerz 1992 ; Latour 1993 ; Richards 1996a).

Organizational entrepreneurship

- 14 Social scientists committed to the philosophical position known as "methodological individualism" (agents making social worlds are free agents) tend, somewhat naturally, to gravitate towards an interest in "shakers and movers" as a central factor in technology generation. The most extreme position is the 19th century stereotype of the "independent inventor". As a matter of fact, however, most technology generation in

the world today takes place in organisations (university, government and private company laboratories and research stations). What is the relationship between managerial variables and research outcomes in such settings ? Who are the people that "make things happen", and how and why do they succeed ?

- 15 Methodological individualists have a strong commitment to the notion of the entrepreneur, and to understanding what entrepreneurs do within organizations, as well as "out there" in the market place (see below).
- 16 We summarise here some features of one such study of organizational entrepreneurship (a comparison of agricultural Research and Development in the USA, India and Nigeria), since this allows us to bring out some strengths and weaknesses of this approach, as a basis for discussing some examples of our own. Among other things, these examples are intended to show that methodological individualism may not always be the best or most profitable standpoint for understanding creative practical thinking about technology generation in development.

Agricultural research in USA, India and Nigeria

- 17 Goldsmith (1990) seeks to understand why agricultural research has been less effective in Nigeria than in India, when both countries endeavoured to copy the successful US model for agricultural technology generation and both received substantial inputs from USA foreign assistance programmes in order to enable them to do so.
- 18 Goldsmith starts his study by summarising the history of organised agricultural technology generation in the USA, and drawing out its major lesson. A highly effective land-grant system of educational, research and outreach facilities for technology generation and transfer to farmers, supported by both state and federal resources, achieved its greatest success in the 1930s and '40s, having grown in a way now known to foster "good (i.e. inventive, adaptive) science". The land-grant institutions worked well because the overall system had grown organically, adapting to local needs and interests, was polycentric, bound together by a complex network of richly productive collaborative arrangements, and operated in a flexible, non-bureaucratic manner well-suited to foster the careers of curious, inventive researchers. That the system worked so well may have been more luck than judgement, partly arising from the fact that it emerged in an advanced industrial (i.e. wealthy) country with a federal political structure. The contrary idea (sometimes canvassed) of mobilizing an army of scientists under a central command structure would have worked nothing like so well- scientists need flexibility, space and resources with which to manoeuvre, and time to pursue their own interests.
- 19 The auspices for the transfer of the land-grant model to Nigeria and India were good. In the 1950s and 60s both were large countries, poised for industrial take-off, with federal political structures.
- 20 Things worked relatively well in India, with clear evidence that the land-grant model helped diversify and modernise Indian agricultural research and extension capacity in time to foster a Green Revolution. The results of the Indian Green Revolution have always been controversial, but from the perspective of the 1990s there is reasonable consensus that the net benefits have been positive (even for the landless poor) after a number of essentially short-term adaptive dislocations. American assistance to Nigerian agriculture produced no Green Revolution, however.

- 21 Both countries started from a similar base line of resources and poverty. The question arises why the recipe worked in one case but not in the other. Goldsmith (1990) isolates five factors that do not account for the greater effectiveness of agricultural technology generation systems in India than in Nigeria :
- lack of investment (per capita more aid money went into agricultural research in Nigeria than in India),
 - lack of human capital (Nigeria has as many qualified agricultural researchers per 10,000 farmers as India),
 - organizational culture (if nepotism, ethnicity, bureaucratic rigidity, and Ivory Tower impracticality were ingrained features of the agricultural R&D system in Nigeria then India was no different),
 - lack of professionalism (after a late start in Nigeria the gap between local and international agricultural science narrowed ; if anything Nigerian scientists became perhaps too much oriented to the views and interests of an international audience of scientific peers),
 - impact of relative prices on institutional development (it is true that artificially low prices for food in post-Civil War oil boom Nigeria undermined farmer efforts at a crucial moment ; but the boom lasted only six years, and during that time agricultural research institutions benefited from greater government investment).
- 22 One factor that might explain the difference between the two countries is that Nigeria faces (by-and-large) more varied and difficult ecological conditions for a country of its size than India. Nigeria has much less land suitable for irrigation and for cultivation of the new semi-dwarf varieties of wheat and rice that were the backbone of the Green Revolution in India. In short, if India had Nigeria's environment then it too might never have seen the benefit of the land-grant model for technology generation. One of us has argued elsewhere that Nigeria's environment is indeed the single most important factor in explaining the under productivity of its agricultural research (Richards 1985). Goldsmith rather slides past this point, acknowledging its potential significance but without reviewing the evidence in any detail in favour of what he considers to be the main source of significant variation when the two countries are compared : viz. organizational structure.
- 23 Goldsmith's explanation for the failure of the Green Revolution in Nigeria concentrates on the following main points :
- agricultural technology generation (as the USA precedent illustrates) is essentially a top-down, elitist project, involving small groups of public-sector entrepreneurs seeking to build organizational empires (this is the way of the world, according to Goldsmith's methodological individualism),
 - in developing country contexts "take-off" for any such projects depends on forging an initial powerful coalition of interests between the three main elite groups of agents (scientific entrepreneurs, the political class, and external advisors/donors),
 - there were clear weaknesses in the Nigerian case in this regard : politicians were not worried (enough) by the needs of their rural constituencies, a civil war was looming, and donors were preoccupied with establishing a new international research centre (IITA) in Nigeria (IITA diverted and polarised interests, creaming resources that in India went to build up national and local regional universities and research institutes),
 - with only weak or divided backing from politicians and donors the organizational entrepreneurs were never able to establish a strong system of national research organizations (the Nigerian research system - by contrast with India or the USA - lacked

local autonomy ; cross-organizational networking and research collaboration were very limited),

- if and when organizational entrepreneurs succeed in priming the technology pump, they must then develop a client constituency to protect their organizational interests. This happened in India where many farmers responded positively to high-yielding varieties, but never in Nigeria. The Nigerian system failed to produce clear successes ; the picture was one of dogmatic extension, resentful farmers and "innovations" with no clear superiority over local practices.

- 24 Goldsmith's account pays too little attention to what farmers in Nigeria were doing - what were their main problems and what kinds of innovations they were engaged in producing. Over-reliance on methodological individualism obscures the extent to which popular innovation in agriculture sometimes arises from collective action by farmers, spread over time (as in the case of the "ancestral programme" for management of plant genetic resources - Richards 1996b) or quite wide distances (e.g. in the field of integrated pest management, or the soil-and-water management measures discussed below). A bias towards elite actors as the prime generators of technological innovation also obscures the extent to which the basic rationale of research systems in both country may have been determined not by objective reality but by the values of the institutional milieu in which scientists operated. Institutional culture can be shown to sharply constrain the field of search for technological options. Below, case study material suggests that a more level playing field is not just a populist preference but a necessity for the "rolling" technology generation/adaptation sequences required for sustainable agricultural development by poor farmers in low-income tropical countries.
- 25 We endorse Goldsmith's emphasis on the organizational milieu but argue that the success and failure of organizational entrepreneurs depends on more than their deals with donors and political elites. Insights from Actor-Network analysis and Culture Theory suggest that a wider
- 26 constituency of support, involving potential clients, is a necessary pre-condition for technological success, rather than its secondary consequence.
Case study : rice research in Sierra Leone
- 27 In 1987-89 Michael Lipton (economist), Adam Pain (plant breeder), and Paul Richards (anthropologist) carried out a comparative study of the relative success of two small national rice breeding systems - Sri Lanka and Sierra Leone. By focusing on two small countries, with a comparable history of colonial investment in research and the same main staple crop, they attained a sharper focus to the Asia-Africa comparison than Goldsmith's more general comparison of the performance of agricultural research systems in India and Nigeria.
- 28 Furthermore, they examined in detail, at farmer level, local responses to research station rice releases, relating this information (in the Sierra Leone case) 10 detailed on-going research into fanner-led varietal selection and management of local land-race materials.
- 29 Economic findings (Lipton et al. 1989) replicate those of Goldsmith for India and Nigeria. It would be correct to talk about a Green Revolution in rice for Sri Lanka (with three successive generations of improved varieties adopted by 80 per cent or more of farm households), and significant increase in yields per capita. Sierra Leone has had no

Green Revolution, with only a handful of improved varieties released, adopted on only about 20 per cent of the national area planted to rice, despite a long history of rice research, and similar levels of donor assistance per farmer.

- 30 Some parts of Goldsmith's explanation would work very well for the Sri Lanka/Sierra Leone comparison. The research entrepreneur/political elite/donor triangle was strong and effective in the case of Sri Lanka, but weak and inconsistent in the Sierra Leone case. The Sinhala political elite in Sri Lanka has a strong ideological vested interest in supporting rice research and agrarian self-sufficiency. Even in times of greatest economic and political adversity, funding for the rice research sector, though never lavish, was protected and assigned the kind of priority normally associated only with funding for the security services.
- 31 In Sierra Leone the political classes make their money out of trade, and transactions associated with alluvial diamond and gold mining in particular. The mining economy of Sierra Leone demands ship-loads of bagged white rice to support the large labour force of tributors working the diamond fields. It has always been more attractive to government to import white rice at subsidised prices (through its monopoly control on foreign exchange and capacity to raise international loans) than to encourage farmers to meet the local demand, though farmers (historically) have shown themselves capable of rising to this challenge when circumstances dictate. In effect, government "disciplines" an otherwise unruly mining sector by controlling its rice supply at source. This would not happen if rice was being produced in situ.
- 32 As far as rural development is concerned, successive governments in Sierra Leone preferred either large-scale schemes that promised to substitute directly for rice imports when donors willingness to connive at the mismanagement of the macro-economy looked to have been stretched to the limit, or extension-oriented schemes that offer patronage to its supporters, rather than a fundamental, research-supported, effort to raise basic agricultural productivities across the entire rice sector. So, far from supporting organizational entrepreneurs and donors to build a strong rice research sector, government (even in the early days of independence) threatened to by-pass research altogether in favour of a succession of bi-lateral and volunteer-run small-scale rice production initiatives. These schemes were based on SE Asian technological blueprints, with little if any attempt to adapt them to the environmental and social realities of the Sierra Leonean rural scene.
- 33 Thus a major feature of Goldsmith's organizational entrepreneurship model - the relative strength of the triangular alliance of organizational empire builders, politicians and donors in Sri Lanka, and its clear weakness in the case of Sierra Leone - helps once again explain the low research productivity of the African system, compared to its Asian counterpart. Goldsmith does not cite Actor-Network literature, but his focus on the apparently decisive significance of the triangle of elite decision making forces is, in effect, a version of the Actor-Network argument. One strength of an explicit Actor- Network approach is that it prompts a fuller and careful mapping of all social links likely to influence the thinking and actions of research decision makers. Once this fuller network structure becomes apparent, culture theory approaches help raise questions about what kinds of "hidden" values might be implicit in networks with different structural properties.

- 34 This is the approach that might then be taken to explaining important aspects of the Sierra Leone-Sri Lanka comparison not well accounted for by a rather narrow focus on elite actors.
- 35 To our mind, the two major unexplained aspects of the comparison are as follows :
- although the Sierra Leone public-sector research system was not as successful as its Sri Lankan equivalent, we still have to explain the fact that it produced some successes (between 5 and 10 superior rice releases from c. 1965-1980 now grown on about 20 per cent of all rice farm land in the country),
 - second, the process through which this adaptive success has been achieved in Sierra Leone (an emphasis on researching the potential of locally-adapted germplasm as well as Green Revolution exotic material) is not dissimilar to the rice improvement breeding strategy pursued over a similar period in Sri Lanka, and in both cases the national system had consciously at times to resist the standard Green Revolution approach in this area.
- 36 Both these points will now be examined in turn.
- 37 *Point 1.* Careful analysis of adoption patterns shows quite clearly that many rice adoptions by all classes of small-scale farmer in Sierra Leone up to 1987 were spontaneous, seed being acquired through informal farmer-to-farmer channels and not as a result of extension service patronage or subsidy. The evidence also shows that farmers re-acquired these varieties if and when they were "lost" through accidents. There is little direct evidence that the modern varieties (MVs) outyield the average for farmers' varieties of rice under local management (IVs). But Lipton et al argue that a straight MV/IV comparison would make sense only if farmers were replacing IV s with MV s. What they do instead, in the Sierra Leone case, is to manage a repertoire of seed choices to maximise output over varied soil conditions. There is clear evidence that farmers do a lot of adaptive testing until they find the niche where an MV performs well within their farm, then squeeze out the least productive IV of its class in their current repertoire. Thus there is no shame in the idea that an MV performs only up to the standard for the farmer's repertoire, since its presence has likely raised the average performance across that repertoire. Thus, researchers must be doing something right, and farmers are fairly vigorously screening breeder's releases, with a mix-and-match mentality, to find out what works where for them at appropriate moments. Although the relevant population genetics surveys have not yet been undertaken it seems quite possible that researchers have, in effect, been strengthening the gene pool for farmer-managed land-races of rice in Sierra Leone.
- 38 *Point 2.* The standard Green Revolution approach to rice breeding in the 1960s and '70s was a product of work at the International Rice Research Institute in the Philippines (cf. Chandler 1972). The first short-straw (semi-dwarf) rices were produced by crossing a Taiwanese variety containing a dwarfing gene with tropical varieties from Indonesia. The IRRI plant ideotype (Donald 1968) was a semi-dwarf, short-duration variety with weak tillering properties. The short, weak-tillering IRRI varieties could be planted at much greater densities (thus utilising more of the available water and sunlight) and more frequently (twice or sometimes three times in one year) thus vastly improving outputs on intensely-worked, well-managed Asian wetlands.
- 39 Sierra Leone farmers still derive more than half their rice from rain-fed uplands. Most farmers make use of a variety of wetland environments for supplementary purposes, and the relative importance of rice grown on wetlands is increasing with time, as

population pressure on land increases. However, few farmers yet have access to well-managed wetland, and lack the labour, in the short term, to improve natural wetlands by levelling them and building water-control structures. Thus an attempt to introduce IRRI-style semidwarfs in the 1960s and '70s was highly premature. What farmers were looking for at the time, and still look for today, were durable strongly-tillering and therefore weed-competitive types suited to upland intercropping and to types suited to variable flood conditions in low-input wetlands, of moderate height and improved earliness.

- 40 IRRI breeders began to recognise these needs in the 1980s, but up to that point Sierra Leone national rice breeders were on their own. In fact they had, at times, to swim against the stream. The story still resonates among rice scientists in Sierra Leone of a visit by an IRRI breeder to Rokupr Rice Research Station in the mid 1960s. Rokupr was set up to solve the problems associated with tidal-pumped wetlands along Sierra Leone's drowned coastline. The IRRI party asked to see the main experimental site, a tidally-pumped polder. When the daily tides receded the visitor met the IRRI semi-dwarf varieties looking rather sorry for themselves by comparison with taller local releases. The local breeders to this day believe that the visitor considered this reflected badly on management of trials of IRRI material by Sierra Leonean researchers, not on the appropriateness of IRRI semi-dwarf material to Sierra Leonean conditions.
- 41 In a way, this visit proved a blessing in disguise, since it minimised the ties between the international and national system that might otherwise have dominated research programmes at Rokupr. If it is true (as national breeders believe) that the international institutions rather looked down upon them, this provided a stimulus for a more locally-focused breeding approach influenced by the breeder G.S. Banya.
- 42 Banya had no formal degree-level qualifications. He had learnt his breeding entirely as a practical skill as a field assistant to an earlier generation of expatriate breeders. Although an experienced breeder of many years standing, Banya's lack of formal qualifications restricted his chances to join the "brain drain" from Sierra Leone. He did not see the need to go "back to school", but reports having spent much of his leave interacting with farmers in his family village in Kailahun instead. This village was a "hot spot" for upland land-races of rice in hilly eastern Sierra Leone.
- 43 During these visits Banya acquired much potentially interesting germplasm, with which he then worked in Rokupr. At a time when the rice research world was agog with the new semi-dwarf IRRI crosses, Banya was working to a different, and older, plant improvement plan, insisting that the potential of locally adapted germplasm had not yet been exhausted. A number of his choices, notably ROK3 and ROK16, were pure-line selections of material he had noted as favourites in the farming community in Kailahun, others were crosses with some local parentage.
- 44 These Banya selections (especially ROK3 and ROK16) are among the most successful and wide-spread of all releases from Rokupr in the past 30 years. ROK3 has had a major impact on upland farmers in NW Sierra Leone where it was hitherto unknown. As a fertiliser-responsive medium-tall, medium-duration variety adapted to both upland and wetland conditions it has been a major success especially in the seasonally-flooded low-fertility boli grassland regions of Sierra Leone. ROK16 is increasingly recognised as a good, blast-tolerant short-to-medium duration variety well adapted to upland farming conditions throughout the country. Its long awns give good protection against

bird damage, a major preoccupation of farmers throughout West Africa. The variety has been successfully introduced into neighbouring countries.

Analysis of the Sierra Leone case study

- 45 Even in the mid-60s, national rice researchers in Sierra Leone were arguing that IRRI short-straw varieties were not suited to local conditions. Provoked by a specific incident, and finding it difficult to get international breeders to take their objections seriously, national breeders, led by G S Banya, followed their own path. Although it was a low-input (and therefore low impact) programme, following this path has produced enough results to confirm that it was not misconceived. Today, the international climate has changed. Rice breeders now take seriously their responsibilities to a majority of farmers working in difficult conditions without good water control. Even so, national breeders in Sierra Leone have not yet had much credit for following a path for which there is now much more international recognition.
- 46 The discovery of this path owes much to the Actor Networks within which Sierra Leone breeders found themselves. "Blocked" from participating as fully as they might otherwise have done in an international network dominated by IRRI perspectives, Banya and others discovered, early on, the merits of what is now called "farmer-participatory" research. Sierra Leone is a small country, and the national research system is too small to be heavily hierarchical. The rural areas are never far from the experience of even the educated elite. Several of the key figures in rice research in Sierra Leone not only came from rural backgrounds, but as Banya's case suggests, are still fully engaged in the social realities of rural life. Banya was not sitting on farms in the village as part of a formal exercise in "participatory research" or plant exploration, but as a member of the local community home "on leave". His sense of where the problem lay, and what might be achieved by the application of technological principles, was not a text-book, or international "jet-set" view of things, but arose, according to his own account in interviews, as an extension of his social engagement in village affairs. Several other key researchers in the Sierra Leone national system have similarly found their own way to a version of agrarian techno-populism through familiarity with, and involvement in, the egalitarian institutions and institutional values that continue to dominate rural life in Sierra Leone. They have had the intellectual self-confidence born of this socialization to "buck the trend", despite a lack of resources, encouragement and recognition.
- 47 The points we want to draw out of this interpretation of events are as follow :
- Actor-Networks that are structured and positioned differently generate different kinds of innovations from the same body of scientific theory,
 - these alternative technical options may be the product of different kinds of socialization, and cannot therefore directly be reached through formalistic attempts at "participatory research",
 - the key factor in the story of rice innovations in Sierra Leone may be the distinct sets of values generated by continued participation in village social institutions (as would be predicted by Culture Theory),
 - it would seem as if rice researchers in Sierra Leone have been involved in a double "hybridization" - between different social institutions (the worlds of formal research and the village), as well as the Latourian hybridization of social forces and technical artefacts.
- 48 More insight is needed into this double hybridization that characterizes the field of agrarian technology generation in SSA. In preparing the ground for theory it seems a

fertile idea to also follow closely some of the ways in which land and water engineers in successful projects were socialized by their working environment. Our examination of three cases shows, in a way not dissimilar to the history of plant breeding discussed just now, that the joint socialization of farmers and engineers interacts with cognitive aspects of both "indigenous knowledge" and "standard" professional practice, to generate viable solutions that are hybrid in both the Latourian sense and the sense that they are mixes of local and "European" values and practices.

Land and water technologies in sub-Saharan Africa
The context of government support for L&W management

- 49 Many governments in SSA have wished to intensify the agricultural use of land to feed growing populations. Officials looked for solutions in plant breeding, large irrigation schemes and mechanized dry land farming. These projects were not always, and perhaps only rarely, successful. In this section we focus on cases of intensified land use that occurred under conditions of farmer impetus and government support.
 - 50 The cases originated in projects that pursued other goals than the intensification of land use. One aimed at food relief through irrigation schemes in an area stricken by drought, another at conservation by having farmers plant grass ridges and build terraces and our third example initially planned contour dikes and dams to protect watersheds against erosion. We will give attention to the social networks from which the schemes, terraces and dams emerged, to the networks through which they spread and to the cognitive shifts that were required from the technicians involved in these networks ; But first we will present the sites and technologies.
 - 51 Persons sailing on a *pirogue* on the Senegal river upstream from the delta see over 800 pumpsets, either floating on the river, on the left bank, or mounted on wheels and located on the embankment itself, on the right bank. When travelling between July and November they hear the engines hum to pump water through 20 cm diameter pipes to the levee 8 - 12 m higher. When the travellers climb across the levee their eyes meet a green rice field of 20-25 ha or its multiple, usually against a backdrop of floodplain forest that survived the scheme and/or new village minarets. The travellers might have difficulty imagining that these fields were not there some fifteen years ago and that people started growing irrigated rice only during the 1980s.
 - 52 Similarly, the Usambara Mountains in east-central Tanzania today contain slopes and sometimes entire hillsides that are the delight of the conservationist. Kilometres of terraces follow the contours of the steep slopes and fruit trees line the terraces or are planted on the terraces themselves. Where the terraces stop, visitors May notice rapidly degrading hillsides or see terraces in the making.
 - 53 Our third example lies in Burkina Faso's North Central Province. Any visitor to the province notices that the gently undulating landscape consists of denuded bill sides meeting arid, nearly treeless plains. Some gulleys menace the road, and other ones have actually ravaged it. Many if not most inhabitants migrate out the area when adult, preferring Burkina's *terres neuves*, Côte d'Ivoire's cocoa plantations or a city. Against these apparent odds, technicians have found a way of weaving two land and water management technologies into the social and economic fabric of the area.
- From food aid to irrigation
- 54 Engineers in the colonial and postcolonial governments of Senegal have, right from the start of this century, planned irrigation schemes in the clayey floodplain of the Middle

course the Senegal river. Taking as given the unquestioned yet social fact that the government wished to use the physical irrigation potential to produce rice to stop imports, they adopted the splitters' view of irrigation development as a purely physical exercise.

- 55 The splitters' view May schematically be said to encourage engineers to first identify sites with sufficient physical potential for rice, e.g. sites where production is constrained by lack of water but that can be linked to a canal conveying irrigation water, that have a gradient of less than 2-3% and a soil composed for at least 30% of clay particles. Once a site has been selected, the size of the scheme is determined, along with the size of the plots. The designer then sets to work, calculating first the water requirements taking into account the climate, the transpiration of the crop and the storage capacity of the soil. He then fixes percentages for the loss of water in the canals due to infiltration and seepage and proceeds to designing a network of canals whose construction requires a minimum of earth movement. The exercise is finished with the prescription of a rotation of the water over blocks of plots.
- 56 If farmers had not already inhabited the plain before the colonial engineers arrived on the scene, this view could have been put into practice. As it was, however, the inhabitants already shaped this plain by felling all trees and bushes in the low lying areas. At these spots the floodwater infiltrates into the soil and sorghum can be grown on the residual moisture once the water recedes. This cultivation practice is vital since in this semi-arid environment rainfed crops succeed only every 2 or 3 years.
- 57 This *aménagement*/adaptation of the floodplain needed to be destroyed if irrigation schemes were to be built. Administration officials rightly feared the resistance that the population might put up against such plans. In 1939 however, with a view to the threat of WW2, the government ran some experiments with schemes for partial water control. These failed, probably due to the unpredictability of the flood level, land tenure conflicts and management conflicts about when to drain the water.
- 58 From that moment on, the government directed its irrigation investments away from the floodplain to the sparsely populated delta of that same river. There it built several 1000 ha schemes for full water control. They were centrally managed, with the farmers in the role of tenants only, formally dependent on the irrigation agency's appraisal of their harvests for a continuation of their yearly lease. The government built only one such scheme in the valley, at Nianga in 1978.
- 59 In the meantime, farmers in the valley experimented with pumpsets on the sites where the government had run its experiments for partial water control. In 1967 an official of Mauritania's cooperatives advised farmers to construct a scheme on the light sandy soil of the levee rather than in the heavy clays of the depression that can hardly be worked by hand. It is possible that this joint farmer-official experiment lies at the origin of an irrigation artefact that farmers and technicians have replicated over 800 times. It consists of a pumpset with a 20 hp diesel engine linked to 20 cm diameter pipes that raise the water 8-12 m to a spilling basin on the levee. From there the water is distributed to about 20 hectares of plots through a network of canals and ditches. The levee land was of little agricultural value before the scheme was built. It was usually cleared by the future irrigators themselves, sometimes with assistance from their government.
- 60 This locally shaped artefact quickly conquered the entire valley. Its quick replication was due to a combination of conditions. Due to population growth, about half the

population no longer had any kind of access to the fertile, vital fields of the floodplain. Per capita agricultural yields must have been dropping for over a decade. The drought that swept the Sahel in the 1970s in some years excluded up to 90% from access to the floodplain and brought the production crisis to a head. The schemes appeared to show a route around the famine. The inhabitants put their Mauritanian and Senegalese governments under pressure to provide quick financial and technical assistance to the farmers. These governments were reluctant at first, as they feared that the village schemes would jeopardize the realization of their dreams for large irrigation in the depressions. Electoral incentives then made the President of Senegal shift his position and act against the wishes of his technicians. He solicited donor governments to supply technical and financial aid for construction. Farmers had enough cash to start up each irrigation season and buy fuel and lubricants thanks to a practice of small trade in the dry season and, especially on the left bank, remittances from male migrants to France (Diemer and Huibers 1990).²

- 61 Suddenly, the farmers opened the valley for irrigation but they opened it for 20 ha schemes on the levees and not for 1 000 ha schemes on the clayey depressions, the type of schemes that the officials had imagined. The schemes are now a fixed part of the valley's farming system and reinforce its weakened wet foot, making the whole system more stable than it probably ever was.³
- 62 The replication of these schemes required considerable cognitive adaptation from the engineers and technicians involved. Very few if any engineers would propose to pump water from a river to irrigate a water demanding crop like rice sown or planted in sandy soil in the semi-arid Sahel. If uttered to colleagues, the engineer would be ridiculed for the idea runs counter to at least five basic precepts. First, a semi-arid climate requires crops that demand little water, like sorghum, mais and millet, not a crop originating from swamps like rice. Second, irrigation schemes should be built on soils that provide much better storage than the sandy levees. Third, rice in particular should be grown on clayey soils capable of retaining much water because rice requires standing water. Fourth, pumping water involves making expenses that must be recovered by selling part of the crop. Eating 80-100% of the crop, like the inhabitants do, makes no economic sense in the normal meaning of that word. Fifth, irrigation requires a type of discipline and rice growing a type of knowledge and capability that people build up only slowly, an idea inspired by the notion of the hydraulic society.
- 63 How did irrigation technicians deal with the cognitive shifts required? One frequent response was to improve the schemes and bring them up to standard. The ditches were straightened that agronomists had designed to follow the contour lines and that meandered through the scheme, totalling more length and therefore losing more water through seepage and percolation than needed if the canals were straight. The schemes were equipped with division structures that would help the farmers to keep the canals straight when maintaining them. Another reaction was to mount a research project to improve irrigation efficiencies. When villages wanted new schemes or extensions but complained of the high pumping costs, technicians pointed to the possibility of building the schemes on the fringes of the levee rather than on top it. Here the soils contain clay particles and the infiltration rate of water is lower. Consequently, from 1985 on, most schemes were built on these fringes.
- 64 How did technicians alleviate the dissonance created in the minds of the majority by the fact that the people spent money on pumping to produce a crop they ate? A

solution frequently heard in European circles was that the schemes were a form of food aid. The conventional economic precept was declared irrelevant because in their view the schemes did not have an economic objective but aimed at social welfare. Not all engineers however, adopted this point of view. There are also examples of engineers who combated the modus of economic operandi. They insisted on the need to grow tomatoes for local factories as a means of generating cash for operation.

- 65 A form of dissonance reduction, heard mostly in Senegalese circles, consisted of pretending that the 20 ha schemes would teach the farmers how to manage irrigated rice so that when at last the government would build the large and technically advanced schemes, it would find an experienced and knowledgeable population.
- 66 The case of the village schemes allows us to make three points. First, the notion of actor networks shaping artefacts should be taken literally and not figuratively. Networks consisting only of engineers came up with concepts for water control that differed in many physical respects from the concept that resulted from the network to which farmers belonged also. These differences concerned the site, the size and the hydraulic infrastructure. Second, the development and especially the replication of the village scheme was favoured by the fact that the President of Senegal needed the votes of the valley's inhabitants for himself and his party to stay in office. For that reason he was willing to override the points of view of his technical planners in the irrigation agency and the Departments of Agriculture and Water Development. His action shows the impact on irrigation development of the balance of power between citizens and government. Third, the network that developed the concept of the village scheme differed from the hundreds of networks that replicated the village scheme, and the replication networks differed again from the networks through which the schemes are today used and managed.

From fodder ridge to terrace

- 67 Let us now turn to the Usambara mountains in Tanzania. The area is well endowed with rain but suffers from erosion. So two projects were agreed by the Tanzanian government to maintain the soil substrat of rainfed maize grown on steep slopes.⁴ They managed neighbouring areas. One had developed a technique that could be expected to be appropriate. It consisted of planting fodder grasses on contour lines. These grasses take up little space, provide fodder for animals if the farmers cut it and take it to their livestock, and require little labour. The idea is to retain the soil particles and allow the water to pass in between the plants. The grasses are to be planted like hedges : 10 cm wide and in high densities to avoid any gaps through which the captured water may assemble and, gushing through in great volumes, make gullies. The concept cannot be qualified as purely physical, since it included references to the use that farmers could make of the hedges.
- 68 The other technique is known as *fanya juu* or throwing soil uphill. It is said to be found in East Africa only. It was introduced in the Usambara mountains by a project technician who had learned the technique in Kenya. At distances of about 1m in altitude a trench 60 cm wide and 60 cm deep is dug along the contour and the soil is thrown uphill. At its new place this soil reduces the slope of the field and therefore the velocity of the run-off water. Over time the field above the trench levels out. The particles that the run-off water separates from the upper part of the field are deposited on the strip of several meters wide at the lower edge of the field because the rise constructed with the soil from the trench slows down the water. In this way the water

helps to bring about a desired state and much less labour is needed than when conventional stone-walled terraces are built. The terraces require more labour however than the contour hedges with fodder grasses. It is quite common for the terraces to be constructed in work parties or through hired labour.

- 69 By 1990 the fodder grass project had made little headway and became increasingly interested in the *fanya juu* project that was successful. Almost everywhere terraces were under construction, a rare sight on any continent and also in SSA. Farmers who had built terraces declared that the labor invested had been returned within 1.2.5 to 2 years. The reason was that the terraces made a larger part of the rainfall available for crop growth. In spite of the high rainfall, water availability for crops had been low because most water ran off immediately and was not stocked in the soil. At the level of the soil, moisture conditions were even similar to those of a semi-arid climate. The new terraces stocked the water and allowed farmers to grow profitable crops like beans and other vegetables, along with fruit trees.
- 70 The explanation of the relative success of the one and the relative failure of the other does not lie in their effectiveness from the point of view of the projects : both technologies keep the loosened soil particles on the field. The explanation lies rather in other features. The grasses on the contour lines store little water in the soil, they mainly produce fodder but this characteristic proves insufficiently attractive. The *fanya juu* terraces stock so much water in the soil that they allow farmers to grow beans. In addition, the technique increases the productivity of the area under trenches : fruit trees planted there produce well because their roots can reach water for which there is no competition.
- 71 What cognitive shifts and social networks can be identified at the level of the technicians ? The fodder ridge project was ready to learn from the *fanya juu* project. It quickly established good working relationships with its neighbour, copied its approach, had its technicians trained, in short incorporated *fanya juu* into its technological offer. The technician of the *fanya juu* project had worked many years in soil and water conservation projects in Kenya where he had gained experience with this technology. The response of the farmers required little adaptation on his part. He was interested mostly in the construction of the terraces and agreed with the reasons farmers had for building them. At the level of the project, the rapid spread of the terraces encouraged the *fanya juu* project to include rural roads in its offer to allow lorries to enter the area and provide more farmers with the incentive for building terraces.
- 72 How do the terraces relate to the social networks of the farmers ? Why do these Usambara farmers wish to grow beans and raise fruit ? Their answer is that it is a new way to make money in agriculture for they can sell their harvests to traders who resell it in the capital. Tiffen et al. (1994) have studied a similar transformation of an eroding landscape into productive and protected one in Kenya's Machakos District inhabited by Akamba. They note an upsurge in terrace construction and intensified land use in the mid 1960s and link it to increasing population densities, education, increased social circulation creating capacity to develop new ideas, access to new ideas through emigration, improved roads, the emergence of nearby markets and to the *fanya juu* concept itself.
- From watershed to ward
- 73 We now turn to Burkina Faso where a donor started a rural development project in the North Central province in 1982 that focused primarily on erosion. The project selected

two major erosion control techniques. (The technical data are derived from Vlaar 1992.) One was the stone row technique. The rows of stones on the fields slow down run off water and encourage infiltration. The technique was copied from the local farmers who are said to have put stones on their fields in a pattern of squares. Many farmers however had not done so because they had to, collect the stones at a point some 5 -15 km away. Here the project intervened by offering the free services of a lorry.

- 74 The other technology was called *digues filtrantes* or permeable dikes. They have a different history. They are made of stones and rocks, built in natural drains. The dikes are 100-300 m long and 0.5-1m high. They slow down run off water. Technical volunteers from a donor country had built them in natural drains near narrow valley bottoms to protect these fertile soils against erosion. Later visits showed that farmers used the strip formed upstream of the check to grow sorghum. Here harvests had improved and stabilised because the run off water had infiltrated and deposited the nutrient soil particles it transported.⁵
- 75 A project member with a Ph D in physical geography embodied the splitter's view of erosion control. He made detailed studies of the transport of soil and nutrient particles in two watersheds. Taking an almost purely physical view of the process and paying no attention neither to socio-economic causes or to farmer strategies, he recommended protecting entire watersheds from top to bottom not only with permeable dams and stone rows but also contour ridges. He favoured using earth moving equipment and paying work gangs both to achieve a quick pace and because farmers would be unwilling to work for free on non-agricultural land. His plan was opposed by the technicians and social scientist on the team. They favoured a participatory approach, in view of the mischief wrought by many public conservation programs that hired labour and earth moving equipment. Either the ridges would break, due both to lack of maintenance and poor construction, wrecking havoc on the fields downstream, or the ridges simply disappeared : ten years later Many of them could not be found, not even with maps. Their emphasis on farmer participation also had strong ideological or ethical foundations.
- 76 The geographer was sent home and the technicians developed what they termed the mini watershed approach (*aménagement micro bassin versant*). They started to work with the groupements villageois de développement, GDs for short. These had been created by the colonial cotton board, had lost their original purpose, and were being revived by the Sankara government as part of its inspired attempt to make the nation stand on its economic feet. Membership of the GDs was not obligatory. Most GDs were dominated by members of the local Mossi elite, some of which had been linked to or were still linked to the hierarchies that composed the old kingdoms.
- 77 Time and again the technicians observed the same pattern of response (Vlaar and Brasser 1990). GDs would react enthusiastically to project proposals to organise non remunerated work parties to construct permeable dams or to load stones on project hired lorries and unload them near farmer fields so that the farmer could place them along the contours to slow down run off water. After some weeks or months, the enthusiasm diminished until no one showed up anymore. It was discovered that the elite dominating the GDs stopped organising the work parties as soon its fields had been equipped with stones and dams, making the other inhabitants disappointed, if not angry.

78 The technicians also observed that work parties that had consisted of persons living in the same wards, usually reached their objectives rapidly and supplied good quality work. More importantly, their enthusiasm did not turn sour. The technicians had also become weary of other disadvantages of the mini watershed approach. It entailed having a greater number of sites than they could realistically supervise, as the plots of the members of the elite were not contingent, and many hours of driving were needed for each hectare protected. In response to the lasting nature of the motivation and the disadvantage of number of hours of driving, they developed a new approach which they termed *aménagement concentré*, which may be translated as block approach. The project decided to bypass the GDs and deal directly with the wards. The result was that the annual production of protected soil multiplied by ten from 300 ha to 3000 ha. It turned out that the wards possessed the group cohesion needed for each farmer to be confident that any labour that he gave to a neighbour's field would be returned to him⁶.

79 In the meantime, the technicians as a group also made a cognitive shift. Since they valued a participatory approach, they depended on farmer willingness to invest labour. During the GD phase farmers had been unwilling to spend labour on non-agricultural fields of the village's territory. During the ward phase all efforts became directed towards investment in agricultural land, and especially valley bottoms. Technical thinking shifted from a public orientation towards watershed protection to a focus on private investment of labour in agricultural real estate through work parties. One should note, however, that individual technicians experienced fewer changes than the project, as no one stayed long enough to live through more than one change.

Land and water management technologies as hybrids

80 The first observation concerns the incompleteness of the splitters' view of irrigation schemes, terraces and dams. The paradigm that many irrigation engineers adhered to, at least during the 1980s, is useless when it comes to understanding how water flows through the canals and fields of a scheme. The reason is that the paradigm excludes all reference to the social links of the Senegalese farmers who operate the scheme.

81 Similarly, in Burkina Faso, the physical geographer conceptualization of the erosion process and the technologies to control it excluded farmer livelihood strategies. Young Burkina farmers compare the return to the investment of labour needed to make the local soil more productive with the labour investment required to settle in Côte d'Ivoire or one of the colonising territories of Burkina Faso. Many of them then opt for leaving the Mossi plateau.

82 The case of the *fanya juu* and fodder ridge projects is slightly different. The fodder ridge project included a reference to the farming system in that it proposed grasses that might be consumed by animals already kept. The *fanya juu* technology has come to include a reference to the possibility of planting banana trees in the trenches because that is what many Kenyan farmers do. So both technologies contained notions outside the purely physical domain. Nevertheless, neither project linked its technology to the new possibility created by the terraces to growing beans and all sorts of fruits for sale.

83 No developer seems to have known that many farmers were on the verge of growing for the market but constrained by low levels of available water in the soil. It remains to be seen whether any anthropologist would have uncovered this. Indeed, it may be doubted whether farmers knew about it before the first terrace was built. It was perhaps the *fanya juu* terrace itself that triggered this idea. These farmers are not

unlike ourselves. When queried in 1975, we would not have asked for machines that would replace our typewriters but we now regularly find new uses for our computers.

- 84 The second observation concerns the interpretive flexibility of schemes, terraces and dams. Our three case studies show that to farmers a 20 ha irrigation scheme is a very different thing than it is to engineers, and that the same applies to the permeable dams and terraces.
- 85 The irrigation schemes in Senegal are viewed by most engineers as sites that belong only to the market economy/commodity circuit. To them, the pumpsets, the construction of the canals and all other infrastructural expenses represent fixed capital assets that, along with all variable expenditures for fuel, lubricants and parts, repairs and so on, need to be recovered by selling produce. To the farmers by contrast, the village schemes are extensions of the cleared depressions in the floodplain that are no longer accessible to all inhabitants. These cleared depressions provide harvest security through the guaranteed availability of moisture, much like the schemes do. The extension link is invisible because not physical but real enough because economic. Farmers consume the sorghum harvested in the floodplain and sell little of it, usually only to defray some immediate expenses. Similarly, during the 1980s they sold only 10-15% of their rice and used part of their harvest to pay the bills of the government agency. To the farmers the [harvests of the] schemes are part of the same social and economic network as the sorghum fields. For short : to many engineers constructing the village schemes, a scheme is a capitalist enterprise and to most farmers it is an extension of the floodplain.
- 86 We have already shown that engineers and farmers had different views on the *fanya juu* terraces. Here, in curious contrast to the village scheme, the non-market conservation goals came from the engineers and the stress on 'capitalist' values from the farmers. To the engineers the terraces were to be put in place for the sole reason that they would stop soil erosion. They saw it as the state's responsibility to prevent any further degradation of the environment To the farmers, the terraces were welcome for the reason that they provided opportunities for lucrative cash crops.
- 87 An almost similar difference may be noted with respect to the *digues filtrantes*. Engineers employed by the state installed permeable check dams in natural drains to protect valuable agricultural soil in the valey bottom. Farmers use them to grow sorghum on the strips of land just upstream of the dams.
- 88 These differences in interpretations of the functions that an artefact fulfils can in a fairly straightforward fashion be linked to the networks that keep farmers and engineers alive. This is however, more evident for the farmers than for the engineers. The engineers give financial interpretations of the irrigation schemes but non-market reasons for their protection and conservation measures. If the literature images technologies as sociotechnical networks (STNs) or hybrids, our case studies indicate that L&W technologies put in place in SSA with the help of government technicians can perhaps be said to be doubly hybrid since the social relationships themselves are also hybrids, mixtures of European and African goals and values.
- 89 The third observation concerns the fact that experiments and non-successful models preceded the development and spread of the village schemes, the *fanya juu*'s and the permeable dams. Before the village schemes were 'invented', the government had, without much avail, experimented with schemes for various types of partial water control and with agency managed full control irrigation schemes. The extension

officers working in Machakos District in Kenya had developed three types of terraces of which only the *fanya juu* ones were adopted. The organisational model for the construction of the permeable dams with their double function of erosion check (European volunteers) and production site (Burkinabè farmers) was the outcome of unsuccessful experiments to link group labour to social control over the labour investment, two of which were described in this paper.

- 90 A fourth observation concerns the differences between L&W STNs that are being replicated on the one hand and L&W hybrids that are being used and maintained on the other. This difference is most marked in the permeable dams. Their construction requires lorry transport, over 200 farmerdays to be supplied in a short rime and technical assistance in designing the dam and pegging it out. The maintenance of the dams however, requires a few hours per year only when the owner replaces a couple of stones. Similarly with the terraces. Constructing them usually requires gang labour, maintaining them means only desilting the trenches, a job that may be done by one person only. Similarly again, the construction of the village schemes requires an extensive network of state agents, who oblige the owners of the site to make it available to the future irrigators and who supply technical and material assistance like earth moving equipment and topographers, politicians who help determine the order in which village schemes are built, village dignitaries and last but not least farmers who invest some 150 working days in clearing the forest and digging the canals. Once in place, the irrigators can manage the schemes by themselves if only there are roads that link them to a filling station, repair shops and an agricultural bank.
- 91 A fifth feature of L&W STNs is the extent to which and ease with which they are naturalised. Akrich (1992) uses this term for technologies that users do not normally distinguish from the natural environment as being artefacts. A case in point is the baking oven that most people who list the technologies in their kitchen, do not mention. Similarly, few 'developers' travelling through the floodplain of the Senegal recognise the cleared depressions as L&W STNs. The same applies to the hillsides terraced through *fana juu*. With time the *digues filtrantes* and even the rice schemes may appear natural elements in the landscape.

Some practical implications

- 92 Let us try to spell out some implications that are practical. At present, many Ministries of Agriculture 1) suppose they know all relevant L&W technologies and 2) disperse their soil and water technicians over all eroding areas. The departments themselves give little systematic attention to evolving technologies that work because they are conceived as STNs and designed as part of the productive system of the farming population. Consequently, each year many technician years are wasted on diffusing standard L&W technologies to populations who decade after decade refuse to take to them.
- 93 A first practical implication might therefore be to make a distinction between on the one hand roving engineers who are to evolve L& W STNs on the basis of farmer reactions and on the other hand resident engineers who replicate these new L&W STNs. The studies show that there is no way for Soil and Water Departments to predict what populations are interested in L& W technologies. One reason is that farmer interest depends on social and physical factors, only some of which are known, and on economic exit options that the department's technicians do not know much about. Another reason is that farmer interest depends on features of the technology itself. In

that case any latent farmer interest can be made manifest only through creative analyses of trials and errors followed by similarly creative synthesising designs. Indeed, much like the way that plant breeders operate.

- 94 A second implication that is practical consists of using labour investment as an early indicator of farmer (dis)interest. In L&W technologies, it is the (labour) investment of the farmer that weaves soil and society into the seamless web that is a STN.
- 95 A common feature of the three successful cases is that they provided the farmers with immediate returns to their labour investment. A third implication therefore seems to be that there is no sense finance programs that cannot prove with farmer response that they meet (immediate) farmer needs. This holds also for intensification of land use through irrigation.
- 96 Another common feature is that the L& W technologies did not cause land tenure conflicts (terraces, permeable dams) or if they caused them, which happened occasionally with the village schemes, they were resolved quickly. On the face of this, it may be concluded that donors should avoid financing L&W technologies that create land tenure conflicts.

Conclusion

- 97 And their joint reflexive monitoring of each other. Whatever the relative power and authority of the two sets of parties, the weaker party (almost certainly, in developing countries, the farmers) have an inviolable veto right ; fanners can simply walk : away from the "best laid plans" of technocrats if these fail to resonate in their lives.
- 98 Distinct life styles and social worlds are imbued with different values. As the case of atomic energy (argued by Douglas and Wildavsky) shows, if these values clash, this clash cannot be simply reconciled by appeal to "reason", since reason itself is an inseparable component of specific socio-technical ensembles. Yet, as the case studies indicate, innovation can and does occur, accompanied by ideological back-tracking to make the unexpected event appear a logical outcome of either party's prior value commitments. This back-tracking is no more than an attempt to save appearances (or face). It would be simpler to admit that making innovation is part of the process of socio-technical world-making (Nelson Goodman). In the development cases discussed above it is world-making jointly essayed by representatives of hitherto distinct social worlds.
- 99 Can this double hybridization be managed to increase the rate at which effective agrarian innovations emerge ? It seems to us that hybridization of socio-technical worlds/life-styles will always be a historic, and place-specific, mix, and therefore no more predictable as an "utterance" than are pithy aphorisms from superficial knowledge of the grammar of the language in which they are uttered. The analogy is very precise - since aphorisms sometimes "break", they therefore make grammar, by extending the range of what is considered to be possible. Engineers "utter" innovations that fanners may judge, initially, to be "grammatically incorrect". But the innovation, by forcing a reaction, opens up a new world of possibilities. Provided the innovation is seen and "read" (many disappear without trace) the situation is changed, whether or not fanners become "adopters". As often as not, they may react by considering the "question" to be correctly posed, but the "answer" deficient - then seeking to respond in different ways of their own devising.

- 100 This suggests that good engineering practice should be based not on the idea of perfected designs, but on a principle of rolling feedback to initiatives that may at times appear as half-baked as they are well-focused. The correct response, we suggest, is not dogmatic adherence to "sound design", but incorporation of farmers' monitoring of researchers' initiatives into the next stage of the design process. An example would be plant breeders carrying out selection experiments on farmer's fields, to see not only what happens in nature but also to monitor how farmers "read" the scientist's experiments, in order to incorporate values and priorities that these readings make manifest into further cycles of selection and testing.
- 101 We concede that there is still need for a fully-worked out theory of this kind of double hybridization - a theory of socio-technical convergence under internationalization/globalization, equivalent to the linguistic theory of language hybridization in a world of global convergence (creolization theory). We suggest that such a theory will not come from a dogmatically-applied methodological individualism, but from a more pragmatic, ethnographic, comparative analysis of social contexts associated with successful technology generation. This theory will not be a theory of what people ought to do, but what they actually do, when handling socio-technical change. It will be a theory of "agrarian creolization".
- 102 Any such theory will have major practical implications for the healthy management of technology generation. The past approach has been dominated by the splitter's perspective. It has led to the deliberate isolation of techno-specialists from allegedly damaging social contexts through the establishment of specialised high-level ivory-tower institutions, of which the rarified Green Revolution research centres might be considered prime examples. Superficial "participation" is unlikely to prove the answer to the isolation and apparent irrelevance of many such facilities.
- 103 Lumpers seek to render social contexts for technology generation not less remote but more real, by promoting a long-term relationship between development technologists and client groups, centred on a "live-in" and "live-by" approach to the fruits of socio-technical hybridization. This suggests that real comparative advantage in these hybrid fields of activity lies with those who are technologically competent and members of local life worlds.
- 104 It was once thought that this live-in relationship between technologists and the fruits of their innovation would be too hard to achieve, in developing countries, when quality work in specialist technical fields was so dependent on highly specialised, place-specific research facilities. But the world has changed. Looser, more effective organizational arrangements in support of "organic [development] intellectuals" working on problems of technology generation can now be envisaged, based on the improvements in telecommunications. "Isolated" national research facilities need no longer be cut off from the global information swim. At the same time further decentralization initiatives might reinforce and extend the hybridization that already occurs between the partially distinct socio-technical worlds inhabited by technology researchers and their clients. If we are correct in claiming that this hybridization explains the unsung successes outlined in this paper, then science policy for developing countries should aim at veritable outpourings of creolized agrarian technologies.

BIBLIOGRAPHY

- Akrich, M.**, 1992, *The description of technical objects*. In : W.E. Bijker and J. Law (eds), *Shaping technology/building society, studies in sociotechnical change*. Cambridge Mass and London, U.K. : The MIT Press, p. 205-224.
- Chandler, R.F.**, 1972, "The impact of the improved tropical plant type on rice yields in South and Southeast Asia". In *Rice Breeding*. Los Banos : International Rice Research Institute.
- Collins, H. and Yearley S.**, 1992, "Epistemological chicken." In A. Pickering, ed. 1992. *Science and practice and Culture*, Chicago : University of Chicago Press.
- Diemer, G. and F.P. Huibers**, 1991, *Farmer managed irrigation in the Senegal valley : implications for the current design method*. End of project report, WARDA/WAU, Water Management Project, St. Louis and Wageningen.
- Diemer, G. and F.P. Huibers**, 1995, *Crops, people and irrigation water : views and practices of irrigation engineers and farmers*. London : Intermediate Technology (forthcoming).
- Donald, C.M.**, 1968, "The breeding of crop ideotypes" *Euphytica* 17 : 385-403.
- Douglas, M.**, 1987, *How institution think*, London : Routledge.
- Douglas, M. & Wildavsky, A.**, 1983, *Risk and culture*. Berkeley : University of California Press.
- Fujimura, J.H.**, 1992, "Crafting Science : standardized packages, boundary objects, and 'translation'". In A. Pickering, ed. 1992. *Science as practice an culture*. Chicago : University of Chicago Press.
- Hannerz, U.**, 1992, *Cultural complexity*.
- Goldsmith, A.A.**, 1990, *Building agricultural institutions : transferring the land-grant model to India & Nigeria*. Westview.
- Latour, B.**, 1993, *We have never been modern*. Harvester Wheatsheaf : Hemel Hempstead.
- Lavigne Delville, Ph.**, 1991, *La rizière et la valise. Irrigation, migration et stratégies paysannes dans la vallée du fleuve Sénégal*. Paris : Syros Alternatives.
- Law, J. and Callon M.**, 1992, "The life and death of an aircraft : a network analysis of technical change." In W.E. Bijker & J. Law, eds. *Shaping technology/building society ;studies in sociotechnical change*. London : the MIT Press.
- Richards, P.**, 1985, *Indigenous agricultural revolution : ecology and food production in West Africa*. London : Hutchinson.
- Richards, P.**, 1996a, *Fighting for the rain forest : war, youth and resources in Sierra Leone*, London : James Currey (for the International African Institute)
- Richards, P.**, 1996b, "Culture and community values in the selection and maintenance of African rice." In S. Brush and D. Stabinsky, eds. *Intellectual property & indigenous knowledge*, Island Press, Covelo CA.
- Rogers, E.M.**, 1983, *Diffusion of innovations*. 3rd Edn. New York : Collier.
- Tiffen, M., M. Mortimore and F. Gichuki**, 1994, *More people, less erosion*. Chichester ; John Wiley and Sons.

Vlaar, J.C.J. (ed), 1992, *Les techniques de conservation des eaux et des sols dans les pays du Sahel*. Wageningen Agricultural University.

Vlaar, J.C.J. and **M.B. Brasser**, 1990, *Mauvaises prévisions de la participation de la main-d'oeuvre à la construction des digues filtrantes au Burkina Faso*. In : Land degradation and rehabilitation. Volume 2 pp. 301-305.

Wolpert, 1992, *The unnatural nature of science*. London : Faber & Faber.

NOTES

- 1.Position paper for the 1996 APAD conference in Stuttgart on negotiated development : brokers, knowledge systems and technologies.
 - 2.For illuminating analyses of other interactions between migrants and farmers on the one hand and the irrigation agency and local development associations on the other, see Lavigne Delville 1991.
 - 3.Compare Claude Meillassoux who in March 1980 predicted in *Le Monde Diplomatique* that 700 000 farmers were heading for famine due to irrigation development in the valley. The well-known anthropologist misread the social shaping process of land and water technology in this part of SSA.
 - 4.I am grateful to Lucia Helsloot and Ton Meijers for refreshing my memory and providing additional information.
 - 5.Source : oral communication J. de Graaf 12 March 1995.
 - 6.After 1990, when a law was approved that uncleared, vacant land could be brought under the ownership of the person who cleared it or otherwise invested in it., enthusiasm grew to the extent that the project decided that it would accept only demands to improve land that had already been cleared.
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