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Multifunctional roads: the potential effects of combined roads and water harvesting infrastructure on livelihoods and poverty in Ethiopia

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Abstract

In rural development, roads are built to improve people's mobility and enhance access to markets, administrative centres, schools and health posts, and are credited with important socio-economic changes. A less studied aspect is the impact of roads on hydrological resources, as roads interact with existing surface and groundwater flows, reorganising the distribution of water related hazards and resources among the population, with significant consequences on their livelihoods. In Ethiopia, the government has embarked in a massive road construction programme over the last decade, mainly to serve the needs of an essentially rural population and agrarian economy. In parallel, the government has also been investing significantly into water harvesting and conservation measures and irrigation to serve the needs of a population whose livelihoods depend heavily on rain fed agriculture. Based on fieldwork conducted in 2014 in the semi-arid region of Tigray, Ethiopia, this article explores the opportunities and potential for multifunctional infrastructures. We argue that two distinctive objectives of improving road connectivity and improving water availability for irrigation are linked and could be served by the same infrastructure, which we call multifunctional roads.

Keywords: roads, groundwater, water harvesting, Tigray, Ethiopia

Introduction

A considerable amount of literature deals with the effects of roads on development and poverty alleviation: in rural areas roads are built to improve people's mobility and connectivity to markets, administrative centres, schools and health posts, and are credited with important socio-economic improvements. However, one aspect that has received little attention is the effect of roads on water flows, and how these positively or negatively affect people. Roads have important consequences on hydrology, blocking and altering the flow of water both in surface and underground. Therefore, roads have the capacity to deeply change the agro-ecology of the places they cross. Poorly planned road infrastructures can have deleterious effects on the assets and livelihoods of people who depend on them. But roads – associated with simple engineering techniques – can also be used to direct surface run-off, collect and retain water and recharge aquifers (Nissen-Petersen, 2006). By providing extra water and sheltering rural dwellers, farmers and herders from floods, droughts and irregular rainfalls, such techniques have the potential to tremendously improve the life and livelihoods of the rural poor in arid and semi-arid regions of the world.

In Tigray, a semi-arid region situated in the North of Ethiopia, the effects of runoff on the landscape are considerable: whereas flows of water and silt triggered by torrential rains devastate the land and people's assets in summer, during the nine month long dry season water becomes the scarce and precious resource on which all life depends. Where surface and groundwater flows and how water can be stored and reused - and by whom - become crucial questions. In the region, soil and water conservation measures have a key role in tackling soil erosion and in improving water availability both for agriculture and domestic use.

Drawing from fieldwork research conducted in 2014 in Tigray this article discusses the potential effects combined roads and water-harvesting techniques may have on livelihoods and poverty reduction. Along the route corridor Sinkata[1]-Hawzien-Abreha Weastbeha-Wukro (Teweldebrihan, 2014), six research sites were selected with a radius of 5 km from the main road. The selection was based on the degree of soil erosion, impacts of run-off, the potential for water harvesting and reuse and the presence of soil and water conservation measures and of irrigation structures (see also Garcia-Landarte Puertas et al., 2014). The features of the road were also incorporated in the sites selection including the functional classification of the road. A participatory assessments (PA) and interviews were carried out in the first four locations, while detailed interviews with community leaders and villagers were conducted in the two last locations. The PA included a participatory mapping exercise, a transect walk, a wealth ranking matrix and seasonal calendars, along with more general discussions on road related changes and impacts. These methods gave us the opportunity to capture both the positive and negative impacts of roads in relation to water resources. Interviews with officials at *woreda* (district) and regional level were conducted to further confirm our findings and to probe the interest, potential and suitability of an inclusive and multifunctional approach to road construction and planning.

[1] Also called Freiweign

The first section explores the contested relationship between roads and development. The second section looks at the case for combined road and water harvesting/storage infrastructure construction approach, and its potential effects on livelihoods and poverty reduction. The third section concentrates on the political economy of roads and the suitability of a combined road/water approach in the case of Ethiopia. In the fourth section, we present some of the findings of the case study, before concluding on the potential for multifunctional roads.

1. Roads and Development: an impressionist portrait

Roads often form an important component of social and economic development theories and poverty alleviation strategies. Modernisation theory argues that the development of transport is conducive to economic growth (Bryceson et al., 2008), an argument back by econometric demonstrations. For instance, based on statistical correlations between economic growth and a host of other factors, and a sample of 43 countries in Asia, Africa, Fan and Rao find that "agricultural spending, irrigation, education, and roads contributed strongly to growth" (Fan and Rao, 2003:29). Overall, the main economic justification for road construction is market integration: "by reducing trade costs and promoting economic specialization across space, transportation infrastructure is said to be a determining factor of growth" (Burgess et al., 2010:2). By opposition "the lack of infrastructure is often mentioned as one of the main reasons of African underdevelopment" (Buys et al., 2006:2) and a deterrent to trade expansion: "overland transport is so difficult and costly that Africa's diverse regions remain largely isolated from one another" (Ibid). This, in turn, acts as disincentive to industrialization (Shiferawa et al., 2012), since manufacturing firms, which are intensive users of infrastructure services, are at a comparative disadvantage. Therefore, economies with poor infrastructure record a low share of manufacturing production in GDP.

Likewise, in rural development roads are "logically assumed to alleviate [...] poverty associated with spatial isolation" (Bryceson et al., 2008:460). The argument is based on the idea that roads provide farmers with access to markets for agricultural inputs, labour, and outputs, and therefore stimulate agricultural production. Based on the observation that poverty is generally concentrated in areas where the market has a weak presence, it is argued that "roads allow the market to infiltrate peripheral areas", and "permit the inhabitants of those areas to access the jobs, services, and higher standards of living in the core" (Rigg, 2002:619). Similarly, Porter argues that roads increase access to social services and markets for the rural poor - schools, healthcare, labour markets, and credit facilities - services that have a direct impact on socioeconomic well-being and human development (Porter, 2003).

However, both in theory and in practice, the links between roads and development have long remained contested. Already in the 1950s and 1960s, Hirshmann argued that investing in transport infrastructure was "costly and unpredictable" (Edmonds, 1998), and that economic growth would lead to the development of transport, not the other way round; Wilson argued that "transport [was] no more an initiator of growth than any other form of investment" (in Edmonds 1998: 26). As some authors demonstrate, there is still a critical lack of evidence regarding roads' consequences in terms of development (van de Walle, 2002). Studies that posit a direct and uncontested link often use inadequate methodologies or lead to unconvincing results (deGrassi, 2005). Wilson notices that often benefits related with road construction are considered so obvious “that they are listed rather than discussed” (Wilson, 2004:525). As a result, “short-term and long-term distributive impacts of transport projects, particularly on low- income groups, are not well understood ” (deGrassi 2005: 53).

One may cite at least three reasons why the link between and roads and development came to be discredited. First, the effects of roads tend to be complex and context specific, and sometimes even negative. Hook and Howe criticize reports and statements that presuppose a direct relationship between road investment, economic growth, and poverty alleviation, for “these statements do not sufficiently specify conditions under which road investments will lead to positive growth or poverty alleviation outcomes” (Hook and Howe, 2005:4). They also warn of the risks that misinformed investments in transport infrastructure may hamper development and harm the livelihood of the poor (Ibid.). DeGrassi shows that increased connectivity can also have detrimental effects through increased competition for workers or through increased imports (deGrassi, 2005). Roads can harm groups of people, villages, and lead to a decline in livelihoods, just as they can contribute to them: the effects of roads are context specific (Rigg, 2002). Roads are sometimes reproached for destroying existing livelihoods, generating environmental destruction, creating disputes over resources, increasing social differentiation, thereby generating social conflicts (Humbert-Droz and Dawa, 2004, Smethurst, 2000, Perz et al., 2007), and increasing the speed of disease transmission and dependency on oil prices (and other imports).

Second, roads do not necessarily serve the needs of local populations, let alone the rural poor, because their needs have been misconceived. In general, the “transport needs of rural population can be characterized as the movement of small loads over relatively short distances” and the predominant means of transport is often on foot (Barwell et al., 1985:130). As a consequence of road construction, non-motorized and intermediate means of transport are sometimes forgotten and displaced from the market (Fairhead, 1992, Fouracre, 2001). In Africa, evidence suggests that roads tend to be over-engineered relatively to the density of traffic (Gwilliam et al., 2008), as traffic remains very low, especially on rural roads. The focus on expensive motorable roads has also created problems for governments because of their maintenance costs (Barwell et al., 1985, Hine and Rutter, 2000). Furthermore, while evidence suggests that benefits often do not accrue to those living outside a 3- to 4-kilometre-corridor along the road (Håkangård, 1992, Porter, 2003), benefits tend to be captured by the wealthiest sectors of the population (Hook and Howe, 2005).

Finally, several authors argue that interventions other than road construction are more likely to alleviate poverty (Hook and Howe, 2005). People’s ability to benefit from the road depends largely on their initial assets: individual landholdings, livestock, and the presence and efficacy of integrated development projects. In general, only “better off communities are able to take advantage of the new opportunities [while] the poor and socially disadvantaged require additional interventions if their capacity to benefit from transport improvements is to be increased” (RAP, 2003:2). Planners have too often focused on increasing mobility through road provision, when the bigger question is that of “accessibility” to social services (Dawson and Barwell, 1993); instead of improving access, such interventions have led to off-road markets and social services being neglected, affecting local growers and more particularly those with reduced mobility. “Roads alone provide an insufficient stimulus for growth in the agrarian sector” (Molesworth, 2001:120).

As far as livelihoods are concerned, roads can benefit rural populations by linking them to the markets and facilitating access to social services and credit; but roads can also have devastating effects, which are more likely to affect the poor. Roads do not act in isolation, and their effects depend on other exogenous factors that frame the (vulnerability) context in which people live. Moreover, if the exact contribution of roads to development is debated and depends on contextual factors, the lack of roads and transport infrastructure can act as a barrier to development. But as the story goes: “roads are not enough” (Dawson and Barwell 1993). To trigger development, roads need to be accompanied by adequate policies – such as education, demonstration schemes, or access to credit – and the right set of conditions – such as existing market and employment opportunities (Demenge, 2012:311). What we want to suggest here is that if improved road access alone is unlikely to positively affect rural livelihoods and trigger development, it is more likely to do so if coupled with other interventions such as improved water availability and irrigations schemes. In this regard, this article argues that improvements can be achieved in strengthening livelihoods of rural dwellers by coupling road infrastructures with water harvesting.

2. (Ground)Water as the missing link between roads and development

Water and livelihoods are intimately interconnected. People need access to clean water for drinking, cooking and household chores, to maintain their health and their dignity. Water also maintains ecosystem services, and is necessary for animal watering and crop production that make up peoples’ livelihoods (UNDP, 2006). Achieving water security is key for food security and poverty reduction (Tucker et al., 2013). Among others, access to clean water supply frees up time for productive activities and contributes to the decrease of water-related diseases. Having access to greater storage and retention of water may increase livestock production, kitchen gardening, and small-scale irrigation. Water also contributes to other small-scale productive activities such as beer brewing and kitchen gardening (Moriarty et al., 2004).

Water availability is even more of an issue for the rural poor who live in arid and semi-arid areas, and are subjected to high rainfall irregularity which leads to frequent draughts, crop failure, reduced vegetation, fodder scarcity, and insecure water supplies (Steenbergen and Verheijen, accessed 01.01.2014). These conditions are worsen by climate change. In the case of Ethiopia, recent climatic trend assessments project further increases in rainfall and more changes to rainfall patterns across the country, including more extreme weather events (McSweeney et al., 2008). Flooding and sedimentation also cause damage by inundating and waterlogging productive land, encouraging growth of undesirable species, and blocking road access and trekking routes. Flooded fields often delay planting, thus reducing yields and quality of crops” (World Bank, 2006:10). In this context, increased water retention and provision can be the key to increase resilience, food and water security, and poverty reduction. Water provision, through water harvesting and storage, would increase the amount of water that could be used by rural dwellers.

Roads – associated with proper planning and simple engineering techniques – can be used to direct surface run-off, collect and retain water and recharge the groundwater system (Garcia-Landarte Puertas et al., 2014). Higher surface and ground water availability would benefit rural dwellers in many different ways, and together with the provision of roads could have a positive socio-economic impact and improve livelihoods. We define these infrastructures as multifunctional roads as they combine several functions, namely transport, access, connection and also water harvesting. This section describes the principles, benefits, and synergies that could result from a combined road/water intervention.

Roads and water are clearly interconnected, although surprisingly little references can be found. As a recent study notes, “The study of the upstream and downstream consequences of rainwater harvesting, and road runoff harvesting in particular, has started to receive attention only in recent years” (Kubbinga 2012: 15). When roads and water are jointly dealt with in the literature (and for engineers) it is rather about the destructive effects of runoff on the road infrastructure than the other way around. However, roads have an important effect on the circulation of water, both surface and groundwater, and the major impact of roads on hydrology and local groundwater availability remain little understood and rather unstudied. For instance, a Transport Research Laboratory publication mentions that roads can provoke soil and channel erosion, often increase the pressure on natural resources, and destroy agricultural land (TRL, 1997).[2] More recently, a World Bank report on Water Resources Development for Ethiopia argues that "failure of traditional road designs to integrate hydrology frequently leads to interference with downstream water use(r)s, as well as inaccessible roads" (World Bank 2006: pp. xiv), but without going into much more details.

Currently, most road construction works have no provision for the storage of run-off water generated from road drainage (Nissen-Petersen, 2006). Moreover, roads are often built with little consideration for hydrology, let alone for groundwater. Garcia-Landarte Puertas et al. (2014) discuss the effects of road run-off on the landscape, among others: uncontrolled flooding downstream roads culvert, waterlogging, gully formation, sedimentation and soil erosion. Griffths et al. (2000) also highlight the negative social and environmental impacts that could occur because of inadequate road planning (e.g. flooding of houses and siltation of farmland) and the economic losses related to it. Furthermore, rainwater running off roads might also cause the death of people and animals trying to cross a flooded road over a riverbed (Ibid.). Hence, poorly engineered road negatively affect people’s assets and livelihoods.

Therefore, the benefits of a road design that would integrate hydrological considerations are double: people would benefit from reduced damage to their assets, as well as from increased

[2] Road construction itself may also lead to environmental issues like pollution (waste, but also solvents, paints, oils, fuels such as gasoline, diesel oil, kerosene, lubricating oils, and grease) and sediment loadings (Griffiths et al. 2000). During the construction, the effects of a temporary labor force on the use and availability of local resources – including water - may also have to be considered.

water availability. Road construction and design can be used to improve the availability and use of groundwater resources. For instance, when it comes to arid regions "by careful design of the road drainage system […] it might be possible not only to protect these sensitive areas, but also enhance natural water supplies and encourage the development of sustainable economic activities by encouraging retention and use of flood water" (Griffiths et al., 2000:7). This can be done by deploying a series of measures such as retaining water in small dams or storage ponds or harvesting run-off from road surface and culverts with deep trenches and rolling dips (Griffiths et al., 2000:16). The literature provides a comprehensive list of features that can be incorporated into the road construction design to control erosion and enhance water supplies and groundwater recharge.

The potential is significant. Nissen-Petersen (2006) estimates that the volume of rain water running off a 1km long road (and 4 m wide) to 96 cubic metres, from a rain shower of 30 mm. Over an entire rainy season, this corresponds to a considerable amount of water that could be used for irrigation or to water livestock, forestry or construction work (see box 1). After treatment (filtration and sterilization) it could also be used for domestic consumption.[3] Synergies would also operate, since people would benefit from increased water availability as well as improved accessibility and access to markets through the road. These could have a considerable impact on the livelihoods of rural inhabitants, at a minimal cost since construction techniques are relatively simple, require only modest equipment, and mostly use local material. Techniques include borrow pits, small and large ponds; ponds with dam (e.g. Charco dams, hillside dams and valley dams); water tanks; subsurface dams (e.g. sand dams, hand dug wells, weirs) and run-off farming through drainage, soil bunds, soil bunds with check dams.

Box1: Potential benefits from road runoff harvesting and storage

Nissen-Petersen enumerates the following list of benefits (Nissen-Petersen, 2006):

1. Tree nurseries, woodlots, orchards and vegetative fencing of fields and homesteads, which provide income from sale of tree seedlings, timber, firewood, fruits, etc.
2. Manufacturing of burnt bricks, concrete blocks, culverts and other building materials that can be sold.
3. Sale of water to neighbours for watering their livestock, construction works, etc.
4. Raising ducks, geese, fish and bees in or near open water reservoirs.
5. Sale of sand harvested from weirs and sand dams in gullies and riverbeds.
6. Recharge of hand-dug wells near subsurface dams, weirs and sand dams in riverbeds from where domestic water can be drawn.
7. Increased agricultural production from fields irrigated by road run-off water.

Studies on rain harvesting as practiced in the Sub-Saharan African region provide further elements of answers regarding the potential and impact of the technique and farmers' output and income. By comparison, based on case studies in Kenya and testimonies of farmers,

[3] However, using run-off water from tarmac roads for domestic use is not advisable due to the risk of contamination by tar, oil, rubber, etc.

Kubbinga found that Road Run-off Harvesting (RRH) systems perform well, boosting agricultural production and farmers' incomes (Kubbinga, 2012). Other benefits reported in his study include: employment creation, selling water to neighbours, raising ducks, geese, fish and bees in or near open water reservoirs, and recharge of wells or dams, all with positive impacts on livelihoods and living conditions. Kubbinga did not observe any negative effect of RRH, but notes the potential health hazards associated with runoff harvested from tarmac roads, which may contain traces of tar, oil and rubber, although these remain largely unstudied (Ibid.). By decreasing runoff and lowering the availability of water downhill, RRH also has the potential to generate conflicts between users. However, noting the significant benefits, the author foresees a large potential for RRH in the drylands of Africa in general.

Furthermore, enhancing integration between hydrological considerations and road design has several implications for improving road infrastructure construction on the one side and strengthening the livelihood of rural population on the other. This has effects both on road construction and agricultural production, eventually influencing food security of rural population.

Indeed, "floods and droughts cause severe damage to roads, making many roads impassable during the rainy season and even during the dry season, due to poor conditions and inadequate river crossings" (Buys et al., 2006:10). Future changes in rain patterns are likely to be "the most influential climate impact on roads in the future" (World Bank, 2010:2), resulting in "increased runoff, increased river flow, soil moisture, groundwater" (Ibid.: 7; see also p.73-4). Hence, water-sensitive road building can contribute to reducing the direct impacts of climate variability and change. But, climate variability also affects the productive assets and therefore livelihoods. Extreme events such as floods and droughts represent key challenges for agricultural production, human settlements and infrastructures. In particular, "Flooding and sedimentation also cause damage by inundating and waterlogging productive land, encouraging growth of undesirable species, and blocking road access and trekking routes. Flooded fields often delay planting, thus reducing yields and quality of crops." (Ibid.).

Thus, "a more integrated, inclusive and dynamic framework for roads planners and designers" that includes water harvesting as a key component of the road design (Garcia-Landarte Puertas et al. 2014:135) will bring positive impacts both for the road infrastructure and for the livelihood of rural dwellers living along and nearby the road.

Yet, adoption of Road Runoff Harvesting (RRH) involves several challenges. Based on experience of RRH in Ethiopia, Kubbinga mentions potential factors that may limit or delay the adoption RRH in the country, notably labour costs, technology, low yield increase or low price of crops, lack of government/donor support, and the unavailability of credit incentives (Kubbinga, 2012). One may also want to add the limited availability of hydrological information, and the additional construction costs. Due to Ethiopia's topography and climate, construction and maintenance costs are already significantly high (Buys et al., 2006). Since "new climate resilient roads are more costly to build" investments budgets will have to be increased (World Bank, 2010:3). However, one may also argue that climate resistant engineering and road construction that better encompass the hydrology will also result in more durable and lower maintenance costs, when water-related damage currently account for respectively 35 and 60 percent of the defects in paved roads and un-paved roads (Buys et al., 2006).

3. Development, Roads and Water in Ethiopia

In order to achieve Ethiopia's development and growth objectives, two of the "strategic pillars" identified in the Growth and Transformation Plan are "maintaining agriculture as a major source of economic growth" and "enhancing expansion and quality of infrastructure development" (MFED:22). The Ethiopian economy is highly dependent on agriculture, and an estimated 85 percent of the population directly or indirectly depends on the agricultural sector (Worku, 2011). Around 90% of the crop production derives from the peasants sector which is characterized by smallholder traditional rain-fed agriculture highly dependent on the occurrence of the rainy season (Devereux, 2009, Tesfay, 2006). Thus, availability of water plays a key role in sustaining agricultural production and in turn improving food security. As we will illustrate in the following paragraphs, both investments in road infrastructures, increased water availability and expansion of irrigation play a key role in relation to the country development.

3.1 Road infrastructure

In Ethiopia, road infrastructure has been defined by the government as "one of the main pillars of its development policy" while rural roads are seen as "one of the decisive factors that highly contribute to social and economic development" (Emmenegger, 2012:9). This aspiration contrasts with the present condition of the physical roadscape, since (Buys et al., 2006) only 25 percent of Ethiopia's area is served by the road transport system, mostly gravel or earth surfaced (World Bank, 2006). The road network is rather sparse: the road density is said to be one of the lowest in Africa, and half the average road density on the continent (Ibid.: 24). In 2002, 70 percent of farms were situated more than half a day's walk from an all-weather road. In spite of this, "road transport accounts for roughly 95 percent of the country's passenger and freight traffic and provides the only form of access to most rural communities" (Ibid.).[4] Moreover, since main roads radiate from the capital, the road distance between regional towns is often enormous, limiting interregional trade and transport.

In order to increase road coverage, between 1997-2010, Ethiopia has implemented a large scale public investment program known as the Road Sector Development Program (RSDP), with significant results in terms of road construction and maintenance (Shumiye, 2010). In a decade, government's spending on roads was multiplied by 10 (Worku, 2011). Between 2004/5 and 2009/10, the government, which has made of poverty eradication its "main development agenda" (MFED:vii) added 11,000 km of federal roads to the existing 36,400

[4] Note that pre-existing non-mechanised forms of transport are omitted here, as it is often the case in the literature. Apart from roads, Ethiopia has 58 airports, including two international ones (Addis Ababa and Dire Dawa) and rail transport is nearly non-existent with the exception of the currently non-functioning Addis Ababa-Djibouti railway.

km long network, reaching a total of 46,800 km of roads, without counting Woreda roads (120.5 km/sq km if community roads are accounted for; see Worku 2011: 3). Efforts were also put on maintenance, with 81% of roads in "good condition" instead of 64% five years before, according to the Ministry of Finance and Economic Development's Growth and Transformation Plan (MFED:13). In 2012, the total network consists of 114,397 km of roads (Emmenegger, 2012).[5] Maintenance and repair still represent one of the largest problems faced by Ethiopia's road network (World Bank, 2010). Yet, in 2006, a World Bank report mentioned that more than half of the network needed to be rehabilitated or reconstructed, while "most of the remaining network [was] either in, or falling into, a state in which routine and periodic maintenance may be insufficient" (Buys et al., 2006:24). Weak management and accountancy represents other key problems in relation to the road development and maintenance (Worku 2011).

Although important during the Derg regime, the focus on rural roads development is rather recent in Ethiopia. Indeed, with the aim of increasing accessibility and transport in rural areas the government initiated the Ethiopian Rural Travel and Transport (sub-) Programme in 2002 and the Universal Rural Road Access Programme (URRAP) in 2011. Both programmes focus on the rural transport network managed by regional and district governments. The first programme looks at questions of access in a multi-sectoral way, covering both transport and non-transport interventions. It aims at improving access to rural areas through rural road development (focusing of low cost roads), reducing the burden of transport and travel through the provision of infrastructures such as water wells, grinding mills, primary schools, health post etc. and improving mobility by increasing availability of affordable means of transport and transport services (ERA, 2013, Emmenegger, 2012). However, it has only been implemented in eight pilot *woredas* (districts); in about 100 other *woredas* the programme is still in a planning/study stage. Needless to say that so far its impacts remain limited. The second on-going programme running in the period 2011-2015 aims at connecting all *kebeles* (lower administrative units in Ethiopia, part of a district) with all-weather roads.

The late focus on rural roads may explain why some authors have denounced a bias towards investment in major asphalt roads, while rural roads and intermediate modes of transport tend to be overlooked (Shumiye, 2010).[6] As a result, the majority of the population living in rural areas is said to be neglected, and lacks access to basic socio-economic facilities (Ibid.). The same authors have asked for measures that "support rather than undermine rural households' animal assets, particularly donkeys, which have served the rural areas so well" (in addition to the importance of tray animals for manure and fuel, although this is not mentioned in the article) as well as the acquisition of wheeled intermediate transport.

[5] The total road network includes 20,429km federal roads, 23,930 regional roads and 70,038km community roads. For a map of the road network, and functional classification of roads, see (World Bank, 2010). In terms of organization, Ethiopian roads are essentially governed and maintained by two different organizations: the Ethiopian Road Authority (ERA), and the Regional Road Authority (RRA.). Roads are functionally classified in 10 different standards, from DS1 to DS10 (only DS1 to DS4 are paved roads. Levels of standard are chosen based on the design traffic flow (Ibid.: 40).

[6] The bias is often justified by donors and economists: "motorway and corridor development should remain Africa's topmost priorities" (Biau et al., 2008:19).

Several studies attempt to measure the impact of roads (or of the lack of roads) on development of the country, although as Worku writes “it is difficult to deal with the socio-economic impact of the sector” (Worku, 2011:2). At the micro-level, evidence shows that rural households in Ethiopia with access to all weather road to the nearest town have higher consumption expenditures (Shiferawa et al., 2012). At a macro level, it has been noted that transport costs account for 50% of export value for Africa’s 15 landlocked countries, to which Ethiopia belongs, compared to 8.6% on the average for all developing countries (Biau et al., 2008). This is likely to act as a serious barrier to national, regional and international trade.

Moreover, given the importance of the agricultural sector, road construction is often justified in terms of agricultural growth: better roads (and all-weather roads in particular) could “deepen the domestic market (…), help to smooth food supplies and prices (..), expand[…] opportunities for off-farm employment [and] help lessen the economic shocks arising from fluctuations in the agriculture sector” (Buys et al., 2006:38). All-weather roads and regional interconnections are seen as “essential in creating incentives for the production of surplus agriculture” and to “enable national trade that will lessen the regional food price shocks of drought and floods, thus reducing dependency on food aid (World Bank, 2010: xxiv).

3.2 Water resources

In parallel, water resources are being developed in the whole country. Between 2004/5 and 2010/11, access to potable water increased from 35% to 49% in rural areas through the provision of wells and water fountains, the construction of 478 harvesting ponds, 3294 rain water collection and 7 run-off water harvesting systems (MFED). Meanwhile, more than 715,000 ha of agricultural land were put under irrigation. Increasing irrigation[7] is depicted as “the most direct strategy to alleviate the impact of drought and ensure food security”, and to “reduce the risk farmers face from climate variability, giving them the incentive to purchase fertilizers, improved seeds, and other inputs that can increase agricultural productivity” (Buys et al., 2006:49). For instance, in the case study area, the availability of a reliable source of water all year round enables farmers to irrigate their fields and rely on a steady income from the land. If ponds enable farmers to retain water and water their fields for two more months at the end of the rainy season, (self-recharging) wells are essential to produce during the dry season. The effects of irrigated agriculture are immediate in terms of food security and income. Many of the participants we interviewed could be totally self-sufficient, or at least had managed to double the number of months they were food secure. Yet, only 2 percent (200,000 hectares) of Ethiopian cropland is irrigated. Hence Ethiopia intends to expand small, medium and large scale irrigation schemes, improve watershed development and “carry out effective water and moisture retaining works” (MFED: 23).

As previously mentioned, agricultural production is the main economic activity in Ethiopia, accounting for 50 percent of the GDP and 90 percent of export earnings (Worku, 2011).

[7] In the 2006 report entitled *Ethiopia: Managing Water Resources to Maximize Sustainable Growth*, the Bank evaluates the tremendous potential of harnessing groundwater resources for agriculture, evaluated at 2.6 billion cubic meters (World Bank, 2006).

Seasonality and climate variability play a key role in agricultural production and food security, since rural households mostly depend on rain fed agriculture. As in the rest of the country, in Tigray rainfall is unpredictable and erratic with a higher concentration between June and August during the wet season when about 70% of the total run off is obtained (Abebe et al., 2012). Rainfall variability, which is one of the highest in the world, is likely to increase with climate change, which makes of effective water management a key challenge for Ethiopia (Jones et al 2013). Soil and water conservation measures, irrigation and better water management have a huge role to play in increasing people's resilience, improving livelihoods and alleviating rural poverty.

4. Roads and Water: insights from the field.

In Tigray, water harvesting for roads is particularly relevant in light of the high rainfall variability, water re-use potential and recent irrigation expansion. In this section, the opportunities for road and water harvesting are discussed in the light of the results of participatory appraisals conducted in Tigray.

Road run-off during the rainy season was mentioned as one of the most threatening impact related to roads and water resource management. In one of the research site, the strong runoff coming from the road had flooded the fields and houses downstream one of the village. It had infiltrated into houses, washed away the mortar, provoked the subsidence of the soil eroded the walls and weakened them, and in at least two cases led to the complete collapse of houses. Similarly, the runoff carried away the topsoil of fields. As it reached less steep areas, the mighty runoff transformed into floods of stagnating water, leaving large areas waterlogged, decreasing people's mobility and risking contaminating groundwater around the hand pump. People also had to cope with destructions generated by the runoff, for instance re-ploughing and re-sowing what had been washed away, clear off the silt, and as a last resort abandon the field. As a consequence of waterlogging and runoff, people grew crops that were less valuable in the market but more resistant: crops with longer stems such as maize, sorghum and finger millet. In a second research site, the elevated road in the wide plain blocked the flow of surface and ground water, resulting in one side being water logged and the other drier with negative consequences on the crop production on both sides of the road.

However, road runoff could also have positive impacts. As a participant once mentioned "Having more water run-off is bad during the rainy season, but more water in wells is good during the dry season" (Anonymous, Tigray, January 2014), so that negative effects at one time of the year could become positive at another. Indeed, several positive impacts related to the (accidental) combination of roads and water-harvesting structures were observed and mentioned by the participants. In several locations, road runoff harvesting was facilitated by the presence along the road of ponds, deep trenches and shallow wells. During focus group discussions, increased groundwater recharge resulting in more water available in wells for irrigation was mentioned as a positive impact of road run-off. In other areas, increased runoff from the road and adjacent areas was canalised to the fields and pastures; as a result fields benefitted and grazing land downstream enriched. In some areas, combined effects could be observed both upstream and downstream. In one site, an Irish bridge had been built to cross a seasonal stream while sand had accumulated behind it, acting as a sand dam. The bridge had increased and spread water retention and moisture upstream, benefitting the cropland. By doing so, it had also decreased and regulated the amount of peak run-off, making it more even across time. While the area used to be severely degraded and had developed huge gullies, the area above and below had become much greener and more forested than before. Trees were planted or grew spontaneously, and grass started growing so that more fodder was available. Later, the cut and carry system had been introduced, while deep trenches had been built to increase groundwater recharge, measures that also contributed to improve the situation. The table below further summarizes the positive and negative impacts related to roads and water harvesting in the case-study area (Tab. 1)

Tab. 1 – Positive and negative impacts related with roads and water (source: our elaboration).

Negative	**Positive**
- Flooding and waterlogging upstream - Decreased moisture downstream (effects on fields, grazing land and livestock) - Runoff redirected and concentrated in culverts, leading to increased and accelerated erosion, formation of gullies and floods downstream - Siltation of fields, ponds and wells - Elevated road blocking the even flow of runoff - Increased runoff leading to the destruction of crops, and the loss of seeds, fertilizer and seedlings - Waterlogging increases the incidence of malaria - Flooding, waterlogging and siltation of fields, making land less productive and more difficult to cultivate, deposit of clay on the land - Loss of arable land due to road, gullies and infertility - Damage to houses: water infiltration, collapse of walls, soil subsidence, and mortar washed away	- Road runoff harvesting and groundwater recharge through ponds, deep trenches and shallow wells - Increased groundwater recharge resulting in more water available in wells for irrigation - Increased runoff from the road and adjacent areas is canalised to the fields and pastures; as a result fields benefit and grazing land downstream is enriched - Increased availability of fodder for livestock - Increased moisture downstream (in some cases) - The water table downstream is more stable throughout the year - Borrow pits can be used to store the water - Diversion of rainwater from erosion gullies to fields - Sand concentrating in gullies - Yields at the hand pump increase - Possibility to cross the river during heavy rains

As one participant summed up “We believe that roads are good for the community, but we are affected by the road runoff, erosion and floods” (Anonymous, Tigray, January 2014). People who leave near the road have to face varied physical consequences of road and road construction, whose impacts seriously affect their assets. Combined roads and water harvesting/storage could enhance the availability of water and ease water shortages, and contribute to improve people’s livelihoods and their resilience.

Conclusion

As it has been exposed throughout this paper, the linkages between roads and development/poverty reduction are unclear. This is partially explained by the fact that the effects of roads are generally complex and contradictory, unequally distributed, and that roads alone are often insufficient to bring changes to the conditions faced by the rural poor. A multifunctional approach to road building increases the chances that the road infrastructure brings fundamental improvements to the conditions faced by the rural poor, notably by improving access to water, and therefore bringing positive impacts on their livelihoods. Such positive impacts could include among others improved physical assets (road, irrigated land, new land under cultivation, ponds); livelihoods diversification (sale of water, commercial agriculture, raising fish, increased demand for labour); reduced vulnerability (seasonal water availability reduced, climate change resilience); and saved time in transport/travelling/irrigation/chores.

The case of Ethiopia, with its large rural agriculture based population, arid and semi-arid climate, and high inter-seasonal and inter-annual rain fluctuations suggests a high potential for multifunctional road infrastructure and rain harvesting, retention and re-use techniques. Moreover, the perspective of a changing climate as well as the large scale road construction programme undertaken by the government and the emphasis on poverty reduction provide the adequate timing for inclusion of multifunctional considerations into the infrastructure development agenda.

However, because the effects of roads are complex, can be positive as well as negative, and because road infrastructure planning and construction that integrate hydrological concerns are recent, the impacts of a multifunctional approach to road construction have to be empirically assessed.

Finally, while concerns for ground/surface water will decrease negative effects that occur because of insensitive road construction methods; these may also increase conflicts, since issues of unequal access to water resources will just add to existing distributional issues of costs and benefits of road construction. Such issues and the protracted negotiations that may result from this situation are also likely to complicate the task of engineers and surveyors in determining the shape and trajectory of the road and water infrastructure. Nevertheless, village politics and questions of access to water resources should first be addressed, so that vulnerable households can be positively discriminated and equal access to water resources can be safeguarded.

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