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WHAT IS THE IMPACT OF INFRASTRUCTURAL INVESTMENTS IN ROADS, ELECTRICITY AND IRRIGATION ON AGRICULTURAL PRODUCTIVITY?

Systematic Review Protocol

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1. Background

In many regions of the world, agricultural productivity has more than doubled since the 1960s in response to the introduction of synthetic fertilisers, pesticides, genetic breeding and irrigation. But despite food becoming cheaper and more plentiful, the global food system is expected to experience an unprecedented confluence of pressures over the next 40 years. On the demand side, global population is expected to increase from nearly 7 to over 9 billion by the 2050s, many people are likely to be wealthier, creating demand for more varied, high quality diets requiring additional resources to produce. On the production side, competition for land, water and energy will intensify, while the effects of environmental degradation and climate change are likely to exacerbate the current situation (Foresight, 2011; Beddington, 2010; Nellemann, 2009).

There is currently significant variation in global agricultural productivity. By raising productivity levels of the lower yielding farms by 80% of that of current high yielding farmers, three quarters (75%) of the additional food required to meet future food needs over the next few decades could be met (CAWMA, 2007). But achieving such increases in productivity is fraught with difficulty – closing the 'yield gap' (the difference between actual and potential yields) will not be easy. Although improved crop agronomy and plant breeding will play a critical role, both in rainfed and irrigated crop production, so too will the various infrastructural services that underpin and support agriculture. Improved productivity will depend not only on better resource efficiency (e.g. fertiliser and water) but also supported by improved access to markets (e.g. rural road networks), infrastructure (e.g. electricity) and finance.

In many developing countries, agriculture is the cornerstone of their economy, the basis of economic growth and the main source of livelihood (Wheeler and Kay, 2010). It is a major contributor to their economies, not only in their gross domestic product (typically ≈25%), but also in merchandising exports (≈ 21%) and most significantly employment (≈60%) (World Bank, 2010). Even though the importance of agricultural development for building economic growth and alleviating poverty in developing countries cannot be ignored, its relative contribution to the economy decreases as the prosperity of a country develops.

Providing support to increase the agricultural productivity of many developing countries (mainly Africa and South East Asia) seems one of the most sensible ways to ensure greater food security and alleviate poverty (Ali and Pernia, 2003). Increases in agricultural productivity (per unit of land and/or unit of labour) leads to income benefits for the rural poor, ultimately enhancing their purchasing power and demand for other goods and services. Low food prices achieved by reducing the costs of production also contribute to lower wages in non-agricultural sectors thus facilitating industrial growth. This excludes any positive impacts that agricultural growth can have on downstream activities beyond the farm gate including processing, post-harvest storage, manufacturing of agricultural equipment, tools and inputs, storage industries and distribution.

Agricultural development also requires increasing the access to a range of services (e.g. finance, raw materials and resources) and providing the means to store, distribute and market agricultural goods. The investment in basic infrastructure needs such as suitable transportation, affordable communications and reliable power generation are all pre-requisites for a successful agricultural driven economy, but in many developing countries these basic attributes for economic development are still lacking.

Transport helps in linking rural areas to aggregate growth. Since the majority of the rural workforce in most developing countries are dependent on the agricultural sector for employment, expanding the road network and improving road maintenance in rural areas can directly translate into lower transport costs for inputs (such as fertiliser) and market outputs since it reduces the travel times for delivery to market and reduces the frequency of transport damage (e.g. vehicles). Gaining improved access to markets also helps farmers to achieve higher consumer demand for their produce. Both lower transport costs and higher demand raises the margin between sales prices and production costs (including transport), resulting in higher incomes and welfare improvements for the rural population (GTZ, 2005).

Investment in irrigation infrastructure can also contribute significantly to agricultural growth as it can help to widen the production options, increase yields, improve quality and help stabilise market supplies, in many cases by mitigating drought effects. Better communications between exporters and importers (transport and telecommunication) allows more timely and safe delivery of goods in response to market demand, thus improving an agricultural sectors' competitiveness (Pinstrup-Andersen and Shimokaya, 2006).

These infrastructural services (i.e. transportation, electricity, telecommunications and irrigation) are all of key importance in stimulating agricultural investment and growth but are still limited in most rural areas of many developing countries (FAO, 1996). In these regions, transportation costs are generally high, productivity is low and the supply of basic inputs and electricity are unreliable, thus reducing the price competitiveness of those countries in international markets. Africa, for example, has one of the lowest road densities in the world - a third of its population live in landlocked countries with poor access to global markets. This situation is exacerbated by armed conflicts and linguistic diversities which leaves a large proportion of Africans isolated from access not only to global but also to domestic markets. For example, it is estimated that it takes an African exporter about 40 days to cross the border into a neighbouring country compared with only 22 days for a Latin American counterpart (World Bank, 2009). However, the quality of infrastructure is as important as its presence (Fan and Chang-Kang, 2005) due to its implications on the speed of transit and transport costs (which are cheaper for paved roads and more stable compared to those for unpaved roads which are costly and vary significantly from season to season).

The absence of spatial and temporal market integration is also a common issue in many low-income countries and is primarily linked to poor agricultural infrastructure and missing markets. This often results in an increase in market supply and drops in local prices in areas of favourable growing conditions, in contrast to other areas which may suffer from deficits in supply and price increases (Pinstrup-Andersen and Shimokaya, 2006).

This protocol defines the framework for a systematic review on the impact of infrastructural investments in roads, electricity and irrigation on agricultural productivity. The protocol describes the research objectives, data searches and extraction strategies, and planned approaches for data synthesis and analysis. The review also has broader international relevance to those engaged in assessments of infrastructure impact on agricultural productivity and rural development.

2. Objective of the Review

As in all systematic reviews, one of the most important aspects is formulating the primary question, which itself is inevitably a compromise between taking a holistic approach, involving a large number of variables and relevant studies, and a reductionist approach that limits the review's relevance, utility, and value. It is proposed that this systematic review principally focuses on three main areas:

1. Rural road infrastructure (incorporating road networks and transport vehicles) and its impact on farmer access to agricultural markets. In this context, the whole transport network is critical – feeder road projects are often linked into poorly maintained and degraded secondary/primary roads and their agricultural impact can diminish as a result;
2. Electricity (supply) and its impact on agricultural crop storage, processing, cooling / refrigeration;
3. Irrigation infrastructure (water storage, access to water, irrigation distribution and application equipment) and its impact on the crop diversity, yield, quality and resilience to drought.

2.1 "What is the impact of infrastructural investments in roads, electricity and irrigation on agricultural productivity?"

Following SR convention, the research question needs to be broken down into components (PICO/PECO) (Table 1).

Table 1 Breaking down the research question (PICO/PECO).

PICO/PECO	Description
Population	Agricultural communities including individual farms, districts and agribusinesses – include both 'food' (cropping and livestock) and 'non food' (fibre, industrial, timber) crops for both internal consumption and export
Interventions	Transport networks (Road density, quality and maintenance of existing networks, transport means) Infrastructure development – including buildings for post-harvest storage, processing, cooling and refrigeration) Electricity supply networks (expansion of the coverage area, new energy sources, reliable supply) Irrigation infrastructure (e.g. canals, water distribution networks, treadle pumps, tube wells, surface/overhead/drip irrigation systems, weather stations)
Comparators	'Before' and 'After', 'With' and 'Without', 'More and 'Less' intervention
Outcomes	Poverty alleviation, human development indicator, changes in farmer incomes and rural economy, employment, changes in cropped/irrigated area, agricultural productivity, food price index, crop/food/livestock production index, environmental impact, energy and agricultural input consumption, market access

3. Methods

3.1 Searches

The database sources, search and organisation websites to be used in this review are summarised in Table 2. Note that this list is not necessarily exhaustive, as others will be inevitably identified during the scoping study.

Table 2 Database sources and websites.

Database sources	Search websites	Organisation websites
ISI Web of Knowledge	google.com	World Bank
Scopus	googlescholar.com	International Fund for Agricultural
Special issues	scirus.com	Development (IFAD)
EBSCO GreenFILE	dogpile.com	Resources for the Future
CSA Natural Sciences		Consultative Group on International
Document Repository		Agricultural Research (CGIAR)
Directory of Open		International Water Management
Access Journals		Institute
ScienceDirect		Asian Development Bank (ADB)
FAO Corporate		African Development bank (AfDB)
Ingenta Connect		Overseas Development Institute
InTute		(ODI)
		Centre for Environmental
		Economics and Policy in Africa

Academic database sources will be sampled first, to avoid duplication later from less specialised databases. Careful attention will be also made to include those journals that have special issues. A maximum of 50 'hits' will be considered from each search website. The search terms to be used in the review are summarised in Table 3. Recent publications and project reports (1990 and onwards) from the organisation websites will be included at this stage.

Table 3 Summary of search terms to be used in review.

Population, subject	Interventions	Comparators	Outcomes
Agriculture	Infrastructure	Selection bias	Poverty; Market outcomes (market access, market integration, market information)
Rural development	Electricity/Energy	Endogenous program	Yield; Productivity
Crop	Telecommunication	placement	Price index
	ICT		
	Irrigation / water		
Livestock	Roads	Conflicts	Economic growth; Food
Developing countries	Dams/storage/water distribution/pump	Collateral damage	security; Employment; Environmental impact; Sustainability; Social impact/education

All references retrieved from the computerised databases (WoK, Scopus etc) will then be imported into a bibliographic software package (Refworks) prior to assessment of relevance using inclusion criteria. The bibliographies of included material will also be searched for relevant references. The review will focus on the literature published in English, the scientific language of most of the international papers. However, reports written in French (the official language in many African countries) will also be included, subject to meeting the defined search criteria.

Searches will not be limited to sources published from 1990 onwards to reduce the effect of the large structural changes that occurred in most of developing countries prior to this date. Even though the study is mostly relevant to Africa and South Asia, these key words and those of any specific countries will not be used as search terms, as this may restrict the search and exclude studies that have taken a wider or global perspective.

Searches were trialled using English language search terms (Table 4).

Table 4 Search terms trialled in Scopus (7th Sept 2011) and number of hits (*and ? denote wildcards).

Search term	All in title	All in topic	Comments
Agricultur* AND (Infrastructure OR Road OR Electric* OR Irrigat*)	778	25,631	Search term too broad but includes all the potential information that might be relevant to this SR
Agricultur* AND (Infrastructure OR Road OR Electric* OR Irrigat*) AND (Rural OR developing countr*)	2	1,732	This limits the research to the interested areas (rural areas and developing countries). This search term is not geographically restricted
Agricultur* AND (Infrastructure OR Road OR Electric* OR Irrigat*) AND (sustainabil* OR Environment*)	52	8,838	This search focuses on the environmental impacts of infrastructural development or the agricultural production sustainability aspects
Agricultur* AND (Infrastructure OR Road OR Electric* OR Irrigat*) AND (Poverty OR Employment OR social OR Education OR Econom* OR development OR Price)	81	10,509	This search is too broad and covers the infrastructural development impacts on the socio-economic situation of rural areas
Agricultur* AND (Infrastructure OR Road OR Electric* OR Irrigat*) AND (Product*OR Yield OR "Food security")	56	11,841	This search includes all the potential impacts of infrastructural investment on agricultural productivity

3.2 Study inclusion criteria

All literature retrieved will be screened for relevance using the study inclusion criteria given below.

Relevant subjects:

- Any agricultural enterprise (individual farms, districts, agribusiness)
- Any country in the world (no geographical restriction)
- The scale of the economy (national/province/village)
- Any agricultural sector (animal/crop/fuel/fibre)

Types of intervention:

- Implementation/rehabilitation of hydraulic works (i.e. dams, pressurized or open channel water distribution systems, pumps, weather stations);
- New transport network and/or improvement of existing transport (i.e. railroads, roads, urban transport, waterways and ports);
- Power distribution network, new power station or alternative energy sources (i.e. hydropower, wind turbine, solar panels), good quality and reliable energy supplies, and;
- Fast, good geographical coverage and reliable internet and mobile phone communications.

Comparators:

Studies must compare either the outcomes before and after project implementation; compare the agricultural productivity of areas with and without certain types of infrastructure; or compare different geographical locations, population density, political stability and economic capacity.

Methods:

Econometric analyses, post-investment appraisal reports, technical assessments (e.g. economic/engineering/financial institutions), case studies, sector analysis reports, academic studies and journal special issues comparing farming livelihoods/production before and after or areas with and without a certain type of infrastructure.

Outcomes:

Impact on agricultural (crop/animal/non-food) productivity and quality, socio-economic impact on the local community or the entire country, increases in employment, market integration (reliable food supply to urban areas) and price competitiveness.

The initial filtering will be undertaken based on the title of the literature source; a second filter will then be used based on the content in the abstract, and then only the full text reviewed for those articles, reports and papers that pass all criteria. This stage will be undertaken by 2 researchers (Knox and Daccache) working independently, to screen the literature datasets. A cross comparison will then be completed to ensure consistency between the 2 researchers in the acceptance/rejection criteria. Literature showing no consistency of agreement between the two reviewers will be discussed and analysed between both reviewers until a decision is agreed. A third reviewer could be consulted if needed.

3.3 Potential effect modifiers and reasons for heterogeneity

Systematic reviews are generally best applied to studies where there is good primary data. This review will be limited to assessing the outputs from a wide range of studies, all of which will inevitably contain a number of 'effect modifiers', including:

- Geographical location (which affects potential agricultural markets, opportunities for trade, competition and hence agricultural development); For example, Mozambique might receive more infrastructural investments than Malawi because it has an extensive coastline that can be used by the landlocked countries;
- Initial infrastructure condition (e.g. absence of basic infrastructure, poor quality infrastructure, insufficient and/or unreliable);
- Availability of natural resources such as water, land and energy;
- Population density and population engaged in agriculture. For example, infrastructural investment may have a higher rate of return in South Asia than in Sub-Saharan Africa because the population density is higher;
- Endogenous program placement. For equity reasons, authorities might target infrastructural investments for less favoured communities which might not have the desired rate of return than the same investment for other communities;
- Efficiency of different political and financial institutions. Some countries are 'donor darlings' for political or strategic reasons or even for having good governance and anti-corruption programs and hence receive more investments than others;
- Colonial and civil wars (e.g. in parts of Africa) might freeze any external investment, lead to demolition of existing infrastructure and fleeing refugees, and;
- Environmental limitations that limit infrastructural development such as negative impact on protected lands (natural reserves, national parks) or damaged ecosystems (over-exploited water resources, clearing productive areas, digging and removing valuable soils).

The extent to which these 'effect modifiers' are present in each study will impact on whether a robust meta-analysis will be possible. For some infrastructural investments (e.g. irrigation) there may be sufficient data available, but the meta-analysis will need to take into account the effect of these modifiers.

3.4 Study quality assessment

To avoid bias, care will need to be exercised in interpreting studies reporting infrastructural impacts across similar agricultural systems but conducted using different methodologies, as there is no single discriminator that can be used to determine which model/approach is best. For example, contrasting economic assessment methods, definition of different key performance indicators, and the appropriateness of temporal and spatial scales, will all have an impact on the reported outputs, and hence result in potential for bias where low quality data might have been used.

In other disciplines, a 'hierarchy of research methodologies' is typically used to score data in terms of its scientific rigour. This approach will not by itself be sufficient in

this SR because the environmental/political/geographical context of each study will provide too much 'internal' variability. However, where possible, specific economic performance indicators will be identified and used for statistical comparison. A checklist will be drafted to help assess quality. Infrastructure development projects/assessment reports are intentionally conducted at country levels, and will be compared to other studies taking into consideration the effect modifiers and all potential sources of bias. The data will therefore be assessed against whether they use recognised econometric approaches, key performance indicators (KPIs), and data sources. Once the data is extracted and imported into the database (Refworks) a field will be added to highlight whether they are from a quantitative peer-reviewed output (or from grey literature (e.g.reports, in-country case studies, technical bulletins) or from other sources (e.g. internet) . Althoguh qualitative research will be included in the SR, the SR findings will be primarily based on objective quantitative data, where possible.

3.5 Data extraction strategy

It is anticipated that a range of empirical data will be identified, ranging from detailed case studies (at the catchment or region level) to more broad-scale national assessments. The approach will be to extract all relevant data based on the 'outcome' search terms and inclusion criteria, and then to tabulate the information by crop type and region using spreadsheets (MS Excel). The data extraction process will be carefully documented for transparency, reporting any reasons for data heterogeneity. The types of data expected to be found are likely to include economic performance indicators (e.g. agricultural GDP, total GDP, product value, output per worker, and output index). These terms will be clearly defined in the SR.

3.6 Data synthesis and presentation

This SR will be based mainly on a narrative synthesis with quantitative evidence where possible. A narrative approach is more suited to studies where the subject content is broad and the range of potential outcomes disparate. However, any quantitative synthesis that can be undertaken using available data will be presented to support the narrative. For example, it may be feasible to apply meta-analysis to some interventions (e.g. irrigation investment impacts on crop yield) if sufficient data are available.

The narrative synthesis will also include quantitative data (presented as tables with means, medians and SD) for particular agricultural sectors or country. One major advantage of the narrative approach is the potential to highlight the gaps in knowledge that exist in this subject, and areas suitable for targeting future programme development.

3.7 Potential sources of conflict and sources of support

There are no known sources of conflict. The study is funded by the UK Department of International Development (DFID).

Keywords: rural; infrastructure; roads, transport; electricity; irrigation; agriculture; productivity; crop; yield

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