

**From Asian Green Revolution 1.0 to  
Sustainable Green Revolution 2.0:**

**Towards a Fertilizer  
Policy for Smallholder  
Agriculture in  
Sub-Saharan Africa**

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Isabelle TSAKOK  
Tharcisse GUEDEGBE

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## **Policy Center for the New South**

Suncity Complex, Building C, Av. Addolb, Albortokal Street, Hay Riad, Rabat, Morocco.

Email : [contact@policycenter.ma](mailto:contact@policycenter.ma)

Phone : +212 5 37 54 04 04 / Fax : +212 5 37 71 31 54

Website : [www.policycenter.ma](http://www.policycenter.ma)

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## About the Authors

### Isabelle TSAKOK

Isabelle Tsakok is an adjunct professor at SIPA and a Senior Fellow at the Policy Center for the New South, previously known as OCP Policy Center, who focuses on rural development, agricultural economics, policy analysis, food security and poverty reduction. She holds a PhD in Economics. Dr. Tsakok has worked on development issues for over twenty-five years, first as World Bank staff and since retirement as a consultant. She has specialized in policy analysis, program and project formulation and evaluation, research and training activities in agriculture, agro-business, rural development and poverty reduction. She has worked in most regions of the developing world: Africa, Asia - South, Southeast and East, North Africa and the Middle East and Latin America.

### Tharcisse GUEDEGBE

Tharcisse Guedegbe is an agricultural economist, researcher engineer at Mohammed VI Polytechnic University, Pole of Humanities Economics and Social Sciences (Morocco), and PhD student at Michigan State University (USA). Before these positions, he served as a research assistant for three years at Policy Center for the New South, a Moroccan Think Tank based in Rabat. His research areas cover inputs use, agricultural productivity, and growth in sub-Saharan Africa, regional integration with emphasis on agricultural trade. He was also interested in the sustainable use of the natural capital in agriculture in Africa. He published several policy briefs, policy papers and contributed to 2018 edition of the Atlantic Currents. Tharcisse holds an engineering degree from Hassan II Agronomic and Veterinary Institute of Rabat.

# Executive Summary

This paper is about the basic principles which should guide fertilizer<sup>1</sup> policy for smallholder agriculture in sub-Saharan Africa<sup>2</sup> It is not about detailed country-specific prescriptions on the “how” of policy. This important task should constitute the substance of detailed country studies. The overarching goal here is to use fertilizer to spearhead and sustain an African Green Revolution (GR). In this paper, fertilizer use is not considered as an end in itself, but as a necessary means to transforming agriculture through sustained and broad-based productivity increases. This dual time frame—short and longer term—and the overarching developmental goal through which fertilizer policy should be viewed has major implications for shaping policy.<sup>3</sup>

For short term results, policy makers must at a minimum give farmers access to: (i) on the input side: the technical package of the GR, namely fertilizer, HYV seeds, pesticides, and water control; and (ii) on the output side: good access to potentially profitable markets.

For longer term, transformational results (several decades at least), policy makers must create and sustain an overall policy and institutional environment in which smallholders’ interests occupy center stage in a way that is compatible and complementary with governments’ financial capability; and society’s legitimate concern for sustainable resource management; and increased resilience to climate change.

What does this mean? For smallholders, it means that they should have secure tenure either as owners or tenants with usufruct rights to the land they till, in addition to the minimum conditions for short term results. For governments, it means that they should carefully consider how to balance their support for private or public goods and services, and the financial pot they can draw upon. For society, it means that the interest for sustainable resource management and for having a resilient agriculture must be furthered.

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1. The term “fertilizer” refers to both organic fertilizer (e.g. manure, compost, etc.) and inorganic (chemical) fertilizer. Thus, a basic goal of “fertilizer policy” is to improve (at least, maintain) the fertility of soils, without which increased productivity, even production, is not possible.

2. Throughout this paper, Sub-Saharan Africa is referred to simply as Africa. The situation in North Africa is not considered.

3. In policy analysis, there is no fixed number of years that is designated as “short” and “long”. In production theory, “short” refers to that period of time within which most factors of production are fixed, not variable. The fixed factors can always be changed but at very high cost. Borrowing from production theory, “short” refers to a period of time within which most farmers have to operate within the constraints of their resource endowment of land, water, labor, and market access. In this paper, this period is hypothesized to be 3-5 years.



# From Asian Green Revolution 1.0 to Sustainable Green Revolution 2.0: Towards a Fertilizer Policy for Smallholder Agriculture in Sub-Saharan Africa

## Introduction

This Policy Paper draws on the comparative experiences of the Green Revolution in Asia, in particular from its two most populous countries: India and China, to identify key elements of a fertilizer policy within an overall development policy.<sup>4</sup> It also draws on selective country experiences of Africa, in particular of Rwanda. It is hoped that the principles derived can contribute to ongoing efforts to launch and sustain a Green Revolution in smallholder agriculture of sub-Saharan Africa (SSA).<sup>5</sup> The main question it addresses is:

What should policy makers do to increase the use and effectiveness of fertilizer as an input into improving the productivity and incomes of smallholders; and in promoting the sustainable transformation of smallholder agriculture and the widespread reduction of rural poverty?

## Approach of Paper

Determinants of fertilizer demand and use as well as its impact on agricultural productivity growth and poverty reduction are multi-causal. While fully recognizing this complexity, this paper focuses on three factors which it hypothesizes as necessary for any fertilizer policy to be effective. They are necessary not sufficient. This focus does not imply other factors are unimportant; but it does imply that without the above sets of factors, the existence of other factors becomes unimportant.

Based on extensive empirical evidence, the underlying hypothesis is:

Effective demand by smallholders is assured when (i) fertilizer is viewed as a key productivity-increasing input within a broader agronomic package that includes inputs such as water; land, improved seed, & research and extension services; and (ii) farmers view their expenditures on fertilizer profitable if they witness consistent crop productivity improvements and have access to lucrative markets for selling their products at a profit.

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4. The overall development policy refers primarily to the development strategy pursued by the country in terms of macro, trade, subsidy and other economic policies.

5. The multi-pronged approach pursued by and the partners of the Alliance for a Green Revolution in Africa (AGRA) are set out in the following website. <https://agra.org/ar-2018/the-agra-way/>

Simply put, the proposition that guides this paper is therefore: Smallholders invest in the fertility of their soil when access to markets enables them to be profitable and when they have land tenure security and water control. This virtuous circle of sustainable fertility, broad-based agricultural productivity and income growth however requires an overall supportive policy and institutional framework maintained for decades by the leadership of a developmental state. Therefore, this paper is not only about promoting the narrow technical package at the heart of the GR but also about this broader framework of support and leadership.

## Scope of Paper

The technologies of the Green Revolution (GR)<sup>6</sup> refer to the development (in the early 1960s) of high-yielding dwarf varieties of staple grains of maize and wheat by the Centro Internacional de Mejoramiento de Maiz y Trigo (CYMMIT) in El Batán, Mexico and then of rice (IR8) by the International Rice Research Institute (IRRI) in Los Baños, the Philippines. Asia adopted these technologies starting in the mid-1960s although China had developed HYV of rice and other grains much earlier. (Fan & Pardey, 1992).<sup>7</sup> The decrease in famine, hunger, and poverty in Asia is largely attributed to the widespread uptake of GR in Asia.

The extent of adoption, modalities, and impact of the GR has varied across Asian countries. This paper analyzes the Asian experience, including in the Philippines, Indonesia, Malaysia, with focus on India, and China. The Asian experience (referred to as GR 1.0) is followed by a discussion of the Sub-Saharan experience, with special focus on Rwanda and on crops with relatively higher fertilizer use in various African countries.

## Organization of Paper

After briefly presenting the approach and the underlying hypothesis of this paper,

- Section I analyzes the Asian experience. Specifically, it discusses the overall policy and institutional environment with important bearing on fertilizer use, as an input in the transformation of smallholder agriculture; e.g., in increasing/sustaining growth in productivity, production, incomes and reducing rural poverty
- Section II discusses Africa's vision for its agricultural transformation—its Green Revolution; the specific commitments African governments must make to translate this vision into action and reality; the important role of increased fertilizer use and progress to date, with particular focus on Rwanda and on selected crops which have the highest fertilizer use.
- Section III sets out principles based on policy insights from Asian and African experiences to guide fertilizer policy—from GR 1.0—for promoting the use and effectiveness of fertilizer as an input into the transformation of smallholder agriculture and widespread rural poverty reduction in sub-Saharan Africa—to sustainable GR 2.0.

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6. The term “Green Revolution” was coined by USAID Administrator W. S. Gaud, hoping these new technologies would help counteract the communist “Red Revolution” viewed as a global threat, that was capitalizing on poverty in developing countries in the late 1960s.

7. In 1956, Chinese agricultural researchers had developed high yielding varieties of rice, responsive to fertilizer and water, yielding 5-6 tons per hectare comparable to dwarf variety IR8 of IRRI of the mid 1960s. In addition, China started its breeding programs for hybrid corn in the 1950s. By the 1960s, the programs had expanded to other widely used crops such as wheat, sorghum, millet, cotton, oil-bearing seeds, and vegetables. (Fan and Pardey, 1992: 58-60).



- The Appendix has tables on main structural changes in the agriculture of India and China (1950s - 2010s); and on Rwanda (1990s and post 2000).

## I. The Green Revolution - The Asian Experience

Salient features of the Asian GR: The GR<sup>8</sup> is a decades-long process, whose main thrust stretched over the 1965-90 period. With priority concern for food self-sufficiency in many countries; e.g., India and China (grain, in particular, wheat and rice), Indonesia (rice), the Philippines (rice), Malaysia (rice), governments subsidized fertilizer use.<sup>9</sup> This subsidization had positive and negative consequences on fertilizer use and its impact as a transformative input for agricultural productivity. On the positive side, price subsidy did expand use as fertilizer was rightly viewed as one input in a broader technical package including water control, HYV seeds and pesticides. Governments invested heavily in irrigation, seed varieties and pesticides, and subsidized the credit farmers needed. Over the decades, Asia put together a set of facilitating conditions<sup>10</sup> which enabled the GR to take off; in particular delivery of research and extension services; assured access to markets at profitable and stable prices. Instituting these facilitating conditions requires critical accumulated levels of investment in agricultural R&D, extension services, roads, irrigation, power and other infrastructure, as well as effective public and private institutions that serve agriculture. (Hazell, 2009: 20) Thus:

- By 1995, total irrigated area in Asia reached 33.2 percent of agricultural area, and average fertilizer use 171.1 kg/ha. (Hazell, 2009: Tab 1)
- By 2000, 80 percent of total cropped area under cereals was allocated to these HYV seeds. (Hazell, 2009: Tab 2).
- Total cereal production grew by an average of 3.6 percent per year (1967-72); cereal production in Asia doubled between 1975-90 ; and cereal yields (t/ha) increased by 99.5 percent (1975-90) in developing Asia.

Public investment and policy support was substantial –by 1972, an average of 15.4 percent; by 1990, an average of 9.6 percent of total government expenditures on agriculture. <sup>11</sup> (Hazell, 2009: Tab 3). Millions were fed even as population increased by 59.6 percent (1970-95). The GR thus made a major contribution to reducing the population in absolute poverty (USD 1/day) by 28 percent, from 1,125 million (1975) to 825 (1990). (Hazell, 2009: Tab 4 & 5, 7-9). With the GR, Asia averted a full-blown Malthusian catastrophe. Instead, through agriculture multipliers, the positive economy-wide impact of the GR was substantial (Mellor, 1976).

Despite impressive achievements, major challenges remain: The GR proved to be a game changer. But there were also negative consequences. A major one is continued fertilizer overuse –not only wasteful but also environmentally unsustainable, undermining the quality of soil and water resources, reducing agricultural productivity and growth over time, as the experiences in the Punjab and China clearly show. Overuse also highlights the chronic problem of deficient extension services: for example, in post-Suharto Indonesia. Following the socio-economic collapse brought about by the Asian

8. The GR process is continuing today to the extent agricultural research and extension services are producing new plant varieties and requiring adjusted cultural practices.

9. The price subsidy was either direct through the prices farmers paid, and/or indirectly through the long fertilizer chain --production, transport and distribution, and in complementary inputs. China however implicitly taxed fertilizer through the prices of nitrogenous fertilizers which were high compared to border prices until 2006. Subsequently, the production chain was subsidized.

10. To a varying extent in different countries.

11. In constant 1985 US dollars.

Financial Crisis (1997-98), investment in public infrastructure and services (e.g., irrigation, research & extension) were severely cut back. Rice yields stagnated and TFP growth in agriculture slowed from an annual average of 2.5 percent (1968-92) to a low of 0.1 percent per year (1993-2000). (World Bank, May 2007: 1, Tab 1.1). Moreover, with large areas planted with relatively few modern varieties, the resulting genetic uniformity is more vulnerable to catastrophic losses in the event of outbreaks of new pests, diseases and climate downturns<sup>12</sup> Furthermore, given the underlying inequalities in the distribution of assets (e.g. land, irrigated water, access to public marketing infrastructure), and given poorly integrated markets for agricultural inputs and outputs, it is not surprising that the distribution of benefits in terms of higher productivity and incomes, favored the better endowed farm households and regions. In India, regional inequalities widened during the GR years, with the incidence of poverty remaining high in the less favored regions. In the Philippines, the birthplace of the HYV IR8, despite annual agricultural growth averaging 4.6 percent during the 1960s-70s, and despite repeated attempts at land reform (under Marcos, Aquino and Ramos), rural poverty hovered between 55 to 60 percent (1991), after a notable decline in rural poverty incidence from around 64 (1961) to 55 (1965) percent.<sup>13</sup> (Balisacan et al, 2004: 231). With reduced though continued poverty, the need for many farmers to purchase their HYV seeds meant an added financial burden. The contrasts and similarities of experiences in fertilizer policies and use between India and China illustrate the strengths and limitations of specific policies promoting fertilizer as a productivity-, production-, and income-increasing input.

### **India and the State of Punjab: Policy and institutional environment for promoting fertilizer**

India was very poor - GDP/capita was 50 USD (World Bank, 1994: 6). At independence (Aug 15, 1947), it inherited a semi-feudal, largely agrarian economy, with a predominantly rainfed, low productivity agriculture. Extreme poverty incidence was estimated at 40 percent of the population which was growing at 2.3 percent per year (1950s-70s). During these decades, per capita economic growth was low – one percent per year. Within this context, chronic food deprivation affected millions; and the specter of famine was ever present. CYMMIT’s HVY wheat (newly developed by Norman Borlaug and his team) was eagerly field tested for widespread dissemination by the GOI in 1965. The GR was launched in India.

Policy and institutional environment (1950s-2010s): Over the long stretch of some 70 years (1950s-2010s), the governments of India (GOIs) pursued (i) an import-substituting industrialization first (ISI) development strategy (1950-mid-80s); (ii) increased market-orientation and trade openness (mid 1980s-2010s). During the first policy period, the GOIs of Nehru and Indira Gandhi favored socialism with its central planning, with extensive regulation, earning the nickname of the “License Raj.” In agriculture, the priority goal was achieving food self-sufficiency, for which the economy had to be protected through high tariffs. Agricultural marketing was highly regulated. In the second policy period, Rao and Singh (1991) pushed through further liberalizing reforms started by Rajiv Gandhi (1985-89)<sup>14</sup>; the main ones included removing the “License Raj”; ending many government monopolies;

12. The absence of such catastrophic losses to date has been due to continued research to broaden the genetic base of varieties supplied to farmers. The international research system spent substantial sums on “maintenance” research to provide national systems with new germplasm to respond to emerging new pest, disease, and climate risks. (Hazell, 2009: 9).

13. Note these were pre-GR years!

14. Rajiv Gandhi (1944-1991), son of PM Indira Gandhi, was the 6th Prime Minister of India (1985-89). He succeeded his mother right after she was assassinated by two of her bodyguards. When campaigning in Tamil Nadu, he was assassinated by a suicide bomber from the Sri Lankan Liberation Tigers of Tamil Eelam (LTTE), on May 21, 1991. (Wikipedia. Last edited Jan 25, 2019. Accessed Jan 26, 2019) [https://en.wikipedia.org/wiki/Rajiv\\_Gandhi](https://en.wikipedia.org/wiki/Rajiv_Gandhi)

reducing tariffs and reducing interest rates; automatic approval of foreign direct investment in many sectors, with Indian states able to directly negotiate with foreign investors and international financial institutions. (Ahmed and Varshney, 2008: 29-31) GOI removed many domestic controls over domestic manufacturing; and reduced prohibitively high tariffs –over 100 percent—which however still remained high by international standards. (Pursell, Gulati, and Gupta, 2007: 6). Nevertheless, India’s economy became more integrated with the world economy –the trade/GDP ratio averaged 40 percent (2016) up from 20 percent two decades ago (1995). (Ahmad et al, 2018: Fig 7A) Per capita annual growth averaged 4 percent in the post 1980 period; and 7 percent per year in the 2010s.

Implementing the GR through fertilizer policy –key institutional and infrastructural changes:<sup>15</sup> Within the first policy framework, India adopted all the recommendations of Sir John Crawford on how to implement GR. His report (1966) recommended “public intervention through price supports and an effective system of grain procurement which would increase profitability by raising and stabilizing prices”. Between 1964 to 1969, prices for rice were raised by nearly a third and for wheat, by half. It also recommended the creation of the Agricultural Prices Commission (APC) to regularly monitor and set minimum prices; and the Food Corporation of India (FCI) to implement an effective price support program. (World Bank, 1994: 9-11) The APC and the FCI remain pillars of India’s agricultural price policy. Marketing of wheat and rice has been guaranteed as a key component of GOI’s promotion of the GR. Other key policy recommendations implemented were:

- substantial increases in fertilizer imports and their allocation to irrigated areas;
- timely supply of high-quality seeds;
- liberal supply of credit to facilitate use of fertilizers and seeds;
- subsidies for fertilizer supplies; and
- reliance on and expansion of irrigation.

Furthermore, in the late 1970s, India adopted the Training and Visit System of agricultural extension (Benor et al, 1984) throughout its states. In conjunction with the adoption of Benor’s T&V Extension system, India invested in building a national agricultural research capability, the India Center of Agricultural Research (ICAR) to serve as an apex organization. (World Bank, 1990) Irrigation infrastructure, both public and private, rapidly expanded from around 21 million ha (1950) of net irrigated area to 42 million ha by 1984/85 (World Bank, Dec 1991: Tab 1.1, 2-3) By 1999-2000, it totaled 57 m ha or 40 percent of net cultivated area. (Chakraborty, 2003: 9) The Federal Government (as of 1965) subsidized fertilizers, while power for irrigation is a state subsidy.

Problematic structural conditions on the ground on the output and input sides: To the extent farmers of rice and wheat could access the system of Minimum Support Prices (MSP), they benefited. However, a majority of smallholders faced difficult marketing conditions which allowed traders to charge margins which they considered excessive for the services rendered by traders. Farmers’ most frequently cited concerns with respect to wholesale markets are inadequate market facilities; high marketing fees; long distances they have to travel; limited market information; inadequate access to credit services; and dishonesty of traders. These problems gave little incentive to farmers to increase production or for traders to discriminate in terms of quality of the agricultural produce offered. (World Bank, 1972: 2) There were problems of access and tenure security on the input side too.

15. Key Structural Changes in India’s Agriculture from the 1950s are set out in the Appendix.

- Access:** Irrigation development was more concentrated in the northwestern states (e.g., Punjab, Haryana, western Uttar Pradesh, northwestern corners of Rajasthan, and Madhya Pradesh). By contrast, in central and eastern India (e.g., Bihar, Orissa, and Assam, east Uttar Pradesh, and much of Madhya Pradesh), irrigation is much less developed. (World Bank, Vol II, 1991: 17-20). Rainfed agriculture predominates in these states and in peninsular India. Some 60 percent of India's vast territory consists of arid, semi-arid, and drought prone areas, totally dependent on rainfall. (Chakraborty, 2003:9, Tab 9) By the early 1990s, it was however clear that the poor performance of the much expanded irrigation infrastructure not accompanied by sustainable financial or environmental management has been burdening the public providers and the private beneficiaries. Low prices to users that do not adequately reflect costs of O&M inevitably lead to poor maintenance/quality. (World Bank, May 2004: 26) The vast irrigation system<sup>16</sup> is in the same vicious circle as the power sector: poor quality and insufficient funds interact to further lower quality and funding.
- Land tenure security:** Independent India inherited a highly unequal land distribution of a semi-feudal agrarian system. At independence, nearly 68 percent of the rural population was landless or nearly landless. India's land reform which was launched shortly after independence had three main components: (i) abolition of zamindars (intermediaries)<sup>17</sup>; (ii) restrictions on tenancy which sought to protect tenants and give them security of tenure; and (iii) ceiling laws on the amount of land beyond which the land can be expropriated for redistribution. Abolition of zamindars is considered the most successful component: it is estimated that 20-25 million tenants benefitted. (World Bank, JL 2007: 38). However, progress on the other two components was initially slow, to accelerate in the 1970s, and then again to slow down in the 1980s. With the exception of a few states (e.g., Andhra Pradesh, Kerala, West Bengal), political commitment to land reform was limited. By the late 1970s -over two decades after land reform was initiated—landlessness was still widespread. Indeed, India had the largest number of rural poor and landless households by the late 1990s. (Hanstad et al: 2009: 241). Small tenant holdings (less than 5 acres, wholly or partly rented) account for the majority of holdings and of all cultivated area in India. (Singh, 1979: xi, 147-148) In eastern and central India which contain nearly 50 percent of net cultivated area, and 80 percent of India's rural poor, (by the mid 1980s), high population pressure resulted in not only very small farms but also a high level of land fragmentation. (World Bank, Vol II, 1991: 19). In addition to tenure insecurity, the land administration system is notorious for being corrupt. Bribes paid annually by users of the system are estimated at USD 700 million, three quarters of the total amount spent on science, technology and the environment! (Deininger, Feb 2008).

Strengths and weaknesses of GOI fertilizer policy exemplified in the State of Punjab: With only 3 percent of India's net sown area, and only 1.5 of its farming population, Punjab produced (by early 2000s) 20 percent of India's wheat, and 10 percent of its rice. These two crops dominate Punjab's agriculture: by the 2000s, they still constituted 75 percent of total cropped area. The trend growth rate (percent per year) of the state domestic product (SDP) from agriculture was 4 in the 1970s, and 5 in the 1980s, well above the national average of around 2.5. It had the highest wheat and rice yields; for wheat and rice, yield growth in the 1980s was 3 and 1.3 percent per year respectively. (World Bank, Sept 2003: vi, 3-5) Fertilizer use was the highest in India at 167 kgs/ha, higher than in

16. India has made one of the largest irrigation investments in the world, but its system is performing far below potential. (World Bank, Dec 1991, (Vol I) Main report: Executive Summary)

17. The zamindars were close allies of the British colonial rulers.

Andhra Pradesh at 160 Kgs/ha (2001-02) (World Bank, Sept 2003: Tab 2.4). But during the 1990s and beyond, Punjab's agricultural annual growth performance slowed down to 2.6 percent, well below the national average that rose to 3.2 percent with the crop sector growing at only 1.3 percent per year. Growth of crop yields either stagnated as for rice, or decreased as for wheat, or was even negative as for cotton which suffered pest attacks. TFP growth of the crop sector which averaged 2 percent in the 1980s virtually stagnated – at 0.05 percent per year during 1990-96. (World Bank, Sept 2003: vi, Tab 2.2, 2.3) The heavily subsidized inputs have not only been contributing to their environmentally unsustainable use but are also regressive. The entire package of heavy subsidies benefit mainly large farmers. Small and marginal farmers who constitute 54 per cent of all Punjab's farmers growing wheat and rice, receive only 21 percent of the financial benefits from MSPs. Small and marginal farmers are an even lesser proportion of all farmers in the state: only 35.5 percent cultivating only 8.8 percent of cropped area. They receive only a minor portion (less than 8 percent) of the canal water, power, and fertilizer subsidies.<sup>18</sup> (World Bank, Sept 2003: 15, 18) These subsidies constitute a major financial drain on the budgets of the GOI and GOP. The high MSPs and the public food grain stocks cost the GOI from 0.5 percent of GDP in the 1990s to 0.8 percent of GDP in 2002/03. For the GOP, the power and water subsidies cost 6.8 percent of agriculture Gross State Domestic Product (GSDP) (2001/02); cost of all input subsidies to the entire state of Punjab, was 10.5 percent of agriculture SDP. (World Bank, Sept 2003: Box 3.1, 19, Tab 3.3).<sup>19</sup> At the national level, the combined fiscal burden of all these subsidies exceeded USD 33 billion or Rupees 2 trillion in 2013 current prices or 11 percent of agriculture GDP. (World Bank Group, 2018: 34).

### **The People's Republic of China: Policy and institutional environment for promoting fertilizer**

At the communist takeover in 1949, China's war-torn economy<sup>20</sup> was very much like India's: very poor,<sup>21</sup> and predominantly agrarian and illiterate. The long 70-years period since then has experienced two radically different economic regimes. The first period (1949-79) was dominated by Chairman Mao;<sup>22</sup> the second by Deng Xiaoping who fundamentally re-oriented China's political economy,<sup>23</sup> and by subsequent GOCs which continued Deng's reforms.

Policy and institutional environment (1950s-2010s): Over this long period, China went through two radically different policy and institutional regimes: the first (1949-79) was centrally planned with a collectivist and highly taxed agriculture; the second (1980-2010s) was of increasing orientation towards markets and foreign trade; and the granting of land usufruct rights to farm households, thus

18. In Punjab, what is considered "large" or "small" etc. is different from the all India average. The different sizes are: Large -above 6 ha; medium-2 to 6 ha; small-1 to 2 ha; and marginal-less than 1 ha. The all-India "large" is above 4 ha. (World Bank, Sept 2003: footnote 11)

19. It has been virtually impossible to remove the subsidies. An editorial in the Hindu stated it thus: "Whether it is procurement prices, power tariffs for irrigation, taxation of agriculture at high incomes, or fertilizer prices, agriculture is always a holy cow that cannot be touched. Unfortunately, the political classes do not realize that by taking such a position, more damage is being caused to the long-term interests of the farming community" (Chakraborty, 2003: 13).

20. Violent conflict raged in China for nearly 50 years - warlords (from early 1900s), then the Japanese army (1937-45), then the civil war (1945-49). It was between the Chinese Communist Party (CCP) under Mao Zedong against the Kuomintang (KMT) or nationalist forces led by General Chiang Kaishek. He fled to Taiwan in Dec 1949, following defeat. On October 01, 1949, Mao Zedong proclaimed the People's Republic of China.

21. GDP/CAP was in the low USD 100s during the Mao period;

22. Mao Zedong (born Dec 26, 1893) died on September 9, 1976. However, economic policies did not radically change until years later. After his death, there was a fierce power struggle, by the Gang of Four. They were arrested in October 1976 and tried in 1981. Jiang Qing, Mao's widow, committed suicide in 1991.

23. Deng Xiaoping (born Aug 22, 1904) retired in 1989, but he remained active as a statesman. He died in 1997 at the age of 92. He gave a fundamental re-direction to China's policy, and China is still reforming. Deng's approach has been characterized as "Socialism with Chinese Characteristics". Many however argue that China's system is "Capitalism with Chinese Characteristics"!

officially recognizing private incentives as valid motivators of economic performance.<sup>24</sup> This was heresy in Maoist ideology.<sup>25</sup> While this greater role for private incentives and markets was being promoted, substantial direct government intervention in the economy continued. China thus ran two parallel systems: liberalizing and controlling as the leadership seemed fit. Though ideologically different, there were striking similarities between China and India. Like India, China under Mao followed an inward looking, industrialization (ISI) first strategy. Both countries also gave top priority to achieving food self-sufficiency<sup>26</sup> as hunger and poverty were widespread in both. With central planning the order of the day, there was pervasive state control on pricing, marketing, transport, etc. Agriculture was collectivized and farm households were rewarded through work points; a system that was disincentivizing.<sup>27</sup> The system of work points was one of the first things Deng Xiaoping dismantled: he endorsed the Household Responsibility System (HRS) in 1981,<sup>28</sup> a move which proved to be a death blow to collective agriculture. The HRS which made households entirely responsible for their profit and loss was simply a return to private farming common throughout Asia. Other key incentive-raising changes followed: e.g., procurement prices for staples were increased; between 1978-83, prices for above quota (voluntary) grain sales were raised by 41 percent and by 50 percent for cash crops; by 1985, forced procurement sales were abolished altogether, except for grain and cotton. From the late 1980s to the early 2000s, China had one of the least regulated domestic agricultural economies in the world. When China joined the WTO in 2001, domestic markets and foreign trade were being progressively liberalized. (Huang et al, 2007: 32-35) With millions of traders competing, the scope of private trading has expanded and markets have become more integrated and efficient. (Huang et al, 2007: 13-14)

Focus on agricultural research & extension, development of HYV, expansion of irrigation and promotion of fertilizer use under Mao: In 1956, Chinese agricultural researchers developed high yielding varieties of rice, responsive to fertilizer and water, yielding 5-6 tons per hectare comparable to dwarf variety IR8 of IRRI of the mid 1960s. In addition, China started its breeding programs for hybrid corn in the 1950s. By the 1960s, the programs had expanded to other widely used crops such as wheat, sorghum, millet, cotton, oil-bearing seeds, and vegetables. (Fan and Pardey, 1992: 58-60). Thus, by the early 1960s, China had already long started its GR as it produced high yielding varieties of rice well before IRRI released IR8. (Yusuf and Perkins, 1984: 53-55). Under Mao's collective agriculture, there was a rapid rise in the use of chemical fertilizers, especially after the fiasco of the Great Leap Forward (1958-60).<sup>29</sup> Use increased from an estimated 22.5 kgs/ha (1962) to 291 kgs/ha (1978). (Srinivasan, 1994: 36). In the earlier decades, fertilizer was taxed. In fact, the "Implicit tax burden arising from the overpricing of nitrogenous fertilizer relative to the world price ... is about three times the explicit agricultural tax" (Lardy, 1984: 60) Taxation through fertilizer pricing lasted into 2006. (Huang and Rozelle, 2018: 498-499) Fertilizer subsidy programs started in the early 2000s. (Li Yuxuan et al, 2013) During the early Mao decades, there was also substantial use of organic

24. These usufruct rights for arable land were extended to 30 years under the Rural Contract Law of 2002. Unfortunately, this law has still not solved the problem of land seizures by local governments without adequate negotiated compensation to farmer households.

25. The key belief under Deng's system is that material incentives and private monetary gain are not incompatible with "socialism with Chinese characteristics". The use of material incentives is an official acknowledgement that they are in fact necessary.

26. Food is equated to grain. Grain consists of corn, sorghum, paddy, wheat, barley, tubers, and pulses.

27. The monetary value of a work point was determined after the entire harvest of the collective was sold and taxes paid. Then the cadres in charge determined the value of each work point and how they were allocated to each member. .

28. The HRS was tried by a small number of communes in Anhui Province in 1978 and spread rapidly. By 1981, 45 percent of production teams have adopted this system.

29. The Great Leap Forward was a push by Mao to change China from a predominantly agrarian (farming) society to a modern, industrial society—in just five years. The results were catastrophic. Between 1958 and 1960, millions of Chinese citizens were moved onto communes. <https://www.thoughtco.com/the-great-leap-forward-195154>

fertilizers, inferred from visitor reports and data on hogs and draft animals, kept mainly on private plots. Extension services were well developed under the commune system, as every commune had members who were trained in new techniques and were responsible for teaching the other members. Every commune also had its own experimental plot. (Nyberg and Rozelle, Aug 1999: 55-56). Mao's period is well known for mass labor mobilizations for infrastructure construction. Agriculture is labor abundant, but land- and water-scarce specially on the North China Plain. Investment by the state in water control—both irrigation and flood control—was substantial since 1949. In the 1950s to the 1970s most of the state's effort was focused on building dams and canal networks, often with the input of *corvée* labor from farmers. Total irrigated area expanded from about 16 million ha in 1949 to about 47 million ha (1980s), of which about 90 percent is from surface sources and 10 percent from groundwater. (World Bank, Feb 1988: 2) Unfortunately, during the reform period (post 1979), funding for agricultural research declined and extension services were also budget-constrained. This decline is shown clearly in the Agricultural Intensity Ratios (ARIs)<sup>30</sup> which declined from 0.45 (1961-65) to 0.39 (1986-88) (Nyberg and Rozelle, Aug 1999: xii-xiii, 5, Tab 14)

Agricultural performance – output, productivity, and structure since the 1950s:<sup>31</sup> Average agricultural growth (1952-80) was 3 percent per year. (Lin et al, 1999: 63-64, 81). Averages in Mao's China are however not meaningful as the period had to undergo extreme political turmoil under the Great Leap (1958-60) and the Cultural Revolution (1966-76). Under Mao's leadership, China developed a cellular economy more on a war footing than on a peace time footing as self-sufficiency (food and otherwise) at a national, even at times at a local/provincial level was a major goal. The economy was thus not organized for efficient growth but for national security reasons. (World Bank, 1994: 3-4) Despite this, grain yields, upon which the entire focus of agricultural policy was, were high by international standards and their annual growth rates (1955-57 to 1979) ranged from one percent (soybeans) to 4 percent (wheat). (Yusuf and Perkins, 1984: Tab 3.7-3.11, 37-41). However, the structure of agricultural output did not change as grains dominated: they occupied some 88 percent of sown area in the 1950s; in 1970, still 83 percent. (Huang et al, 2007: 5-6). The transformation of China's agriculture started only during the Deng period of reforms. From 1978-84, annual agricultural growth rate doubled to 7.1 percent, then declined to 4 percent (1985-95) and to 3.4 percent (1996-2004). (Huang et al, 2007: 10).<sup>32</sup> AG/GDP ratio fell from nearly 70 percent in 1952 to under 10 percent by the 2010s. The dramatic transformation was also evident in the relative decline of grain in favor of higher-value cash crops (e.g., cotton, vegetable oils, vegetables and fruit); livestock and fisheries. (Huang et al, 2007: 11-12). Agriculture diversified substantially: in 1978 crops dominated; by 2005, the contribution of livestock (mostly pork and poultry), fisheries & aquaculture contributed to almost 50 percent of AG GDP (35 and 10 percent respectively). (World Bank, 2012: Box A) Productivity growth from 1979-1984 was dramatic: TFP grew between 5-10 percent per year; from 1985 to the mid-1990s: at 2 percent per year, a high level by international standards (e.g., TFP in the agriculture of the EU, USA and Australia grew around 2 percent per year in the post WW II period) (World Bank, Govt of China, 2012: 16).

Chinese farmers apply too much fertilizer, undermining resource quality, environmental sustainability and productivity: Under both policy periods, fertilizer use was high. In fact, China has the opposite problem of sub-Saharan Africa: Its farmers overuse fertilizers. Average application rate in China (kg nutrients/ha) is 428 versus 115 world average. China's Nitrogen Use Efficiency (NUE) is low compared

30. ARI measures agricultural expenditures as a percentage of AGGDP.

31. Key Structural Changes in China's Agriculture from the 1950s are set out in the Appendix

32. An updated estimate is in Huang and Rozelle (2018: Tab 24.1), the annual growth rates (percent) are: 2.2 (1952-78), 6.9 (1978-84) and 4.5 (1978-2016). In both sets of estimates, the sustained growth rates transform agriculture over time.

to world level:<sup>33</sup> estimated at 25 percent (2010) versus world level at 42 percent (Zhang et al, 2015) or estimated at 28 percent (2009) versus world level at 47 percent (Lassaleta et al, 2014). (Heffer, 2016) A contributing factor to this problem is: extension services were privatized in 1988. The extension agents oversold fertilizers as the agents were encouraged to engage in commercial activities. The risk of N losses is high; or in other words, the risk of soil leaching is high, with serious environmental side effects (Bentrop and Palliere, March 2010). Over the last three decades, China has been the fastest growing fertilizer market, with one of the highest average fertilizer application rates in the world. In the 2010s, it has accounted for some 30 percent of global fertilizer use. Such overuse was made evidently clear through a major decade-long project through which 21 million farmers were given detailed evidence-based agronomic recommendations including the amount of fertilizer to use. The project also mounted a major dissemination/education effort. The recommendations for maize, wheat and rice led to crop yields increasing by 11 percent while fertilizer use were reduced by an average of 15 percent per crop. So, the farmers produced more with less! (Harris, 2018). Professor Zhang Weifeng of the Agricultural University of Beijing won the International Fertilizer Association Norman Borlaug Prize (2018) for steering Chinese farmers towards more efficient fertilizer use while also improving fertilizer use. (Farming First, Nov 1, 2018)<sup>34</sup> He developed a fertilizer data base that enabled one to identify inefficiencies in fertilizer use. It is therefore clear that there is potential to reduce the use of fertilizer by 30 percent without reducing output; while contributing to cost savings and reducing environmental problems. (World Bank, Govt of China, 2012: Box A).

## II. Sub-Saharan Africa—Fertilizer for the African Green Revolution

### Fertilizer strategy: the African commitment

The CAADP vision for Africa’s agricultural transformation: In 2003, African heads of state ratified the “Comprehensive Africa Agriculture Development Program (CAADP)” that synthesizes the African vision of agricultural transformation.<sup>35</sup> The leaders commit to two targets: to achieve 6 percent of annual growth in agricultural productivity and to allocate at least 10 percent of the national budget to agriculture development and establishment of appropriate investment climate. The four pillars of CAADP are: (1) “Extending the area under sustainable land and water management”; (2) “Improving rural infrastructure and trade-related capacities for market access”; (3) “Increasing food supply and reducing hunger”; (4) “Agricultural research, technology dissemination and adoption”. CAADP pays attention to the improvement of soil fertility and technical progress to improve productivity and make better use of soil nutrients. Three years after its establishment, through the Abuja Declaration on Fertilizer for the African Green Revolution, African leaders also commit to increase fertilizer consumption per hectare to 50 kg by 2015.

Key measures to translate vision into action: To achieve this objective, African leaders are committed to taking bold and appropriate measures to reduce the cost of fertilizer procurement, to developing and scaling up input dealers and community-based networks, to strengthening the capacity of youth,

33. The NUE – Nitrogen Use Efficiency - measures the efficiency with which fertilizer is applied in crop production.  $NUE = \frac{\text{of N removed through production}}{\text{N inputted through mineral N application}}$ . A low NUE efficiency means N fertilizer input exceeds total crop demand.

34. Farming First. Nov 1, 2018. “Professor Weifeng Zhang wins IFA Norman Borlaug Prize” <https://farmingfirst.org/2018/11/china-agricultural-transformation/>

35. AU’s Second Ordinary Assembly held in July of 2003 in Maputo, Mozambique



farmers' associations, civil society organizations and the private sector. They are also committed to increasing farmers' access to input and output markets as well as their access to appropriate services by accelerating investments in infrastructures, implementing targeted subsidies, strengthening farmers' organization and providing fiscal incentives. They also pledged to provide appropriate support to input suppliers by establishing national financing facilities that will accelerate their access to credit at both the national and the local level. Given underutilization of the fertilizers' raw materials within the African continent, African Union Member States decided to promote national and regional fertilizer production and intra-regional fertilizer trade and have decided to establish an Africa Fertilizer Financing Mechanism (AFFM).

Financial constraints of AFFM to increase fertilizer manufacture capacity in Africa: Potential activities to be financed by the AFFM are related to: Developing Africa's fertilizer manufacturing capacity, providing credit guarantees for fertilizer importers and distributors, establishing regional fertilizer procurement and distribution facilities, developing policy instruments, and, institutional, research and capacity-building activities (AFDB, 2007). However, operationalization of the AFFM is currently facing certain constraints, especially difficulties to mobilize financial resources. A 2010 progress report of NEPAD stated that approximately US\$ 5,455,892 has been contributed so far to the AFFM account (mostly from Nigeria), leaving a shortfall of US\$ 4,544,107 that is required for the Fund to be legally operational (Wanzala M. , 2011). In 2011, NEPAD called for immediate commitment of funds from national budgets to bridge this funding gap and asked the African Development Bank to embark on an aggressive fund-raising drive to encourage external donors to commit funds to the AFFM (NEPAD, 2011).

Need to increase fertilizer use substantially among smallholders: Currently, only a few African countries record fertilizer consumption that exceed 50 kg per hectare (Guedegbe & Doukkali, 2018). The average level of fertilizer use per hectare is around 15 kg. Fertilizer adoption and use or more broadly the integrated soil fertility management remain a main concern in the regional and national agricultural policies. Integrated soil fertility management is one of the six priority fields of action of ECOWAP (Economic Community of West African States Agricultural Policy; (ECOWAS))<sup>36</sup> and the National Agricultural Investment Programs (the national version of CAADP). These highlight concrete measures and expected results in terms of increasing the intensity of fertilizer use.<sup>37</sup>

### **Fertilizer strategy, policies and experiences at country level—Rwanda: agriculture and economy**

Remarkable progress in agriculture, a pillar of Rwanda's economy: Rwanda is the African country that has recorded striking performances in recent years, not only in terms of fertilizer consumption, but also in terms of overall agricultural transformation; hence of major interest in this paper. The African Union, through the African Agricultural Transformation Scorecard (AATS), designated Rwanda as the country that achieved the most progress with respect to the Malabo Declaration goals and targets by 2025 (African Union, 2017).

36. Economic Community of West African States.

37. In the case of the Nigerian National Agricultural Investment Program (FMARD, 2010), it has been defined that NAIP will undertake a national soil testing exercise aimed at determining the nutrient status of soils so as to provide a guide for appropriate fertilizer use that are crop specific and environmentally friendly. NAIP resources will be expended on such activities as fishery terminal, fertilizer quality control, seed certification, capacity building of farmers and extension agents; interstate pest control post, among others. The medium-term outcomes of the NAIP are defined as consistent with the goals of the National Food Security Program. One of the main goals is to increase by 30 percent the use of fertilizers by farmers across the country.

Remarkable economy-wide progress as well: Rwanda's economywide progress has also been recognized. In this small, landlocked, open country (trade represents almost 50 percent of GDP), it has a densely packed population of about 12 million people and a population density of around 499 people per square kilometer in 2018. The Gross National Income (GNI) per capita more than tripled in the two decades following the genocide, a much higher increase than the regional average. From a low GNI/cap of USD 150 (1994) the year of the genocide, it has risen from USD 250 (2000) to 780 (2018).<sup>38</sup> According to the World Bank, the poverty rate dropped from 77 percent in 2000 to 56 percent in 2016, together with a significant reduction in child mortality and near-universal primary school enrollment. Some 97 percent of Rwandan children attend primary school and this is the highest rate in sub-Saharan Africa (Howard, 2014). The government's electricity access grew (percent) from 9 in 2009 to 42 in 2018.<sup>39</sup>

Rwanda's agriculture—key features and importance: The sector occupies approximately 72 percent of the active population, especially women, and contributes around 33 percent of the national GDP; up to 70 percent of export revenue; and about 90 percent of national food needs (IPAR, 2015). Its sub-sectors, including food crops, export crops, and livestock, contribute to boosting economic growth. Fifty-two percent of the total land area is considered suitable for agriculture production and 90 percent of that total is on hillsides. The main staple crops grown are cassava, Irish potato, maize, rice, sweet potato and wheat, while the main commercial crops are coffee and tea. Most agriculture farmland is in the hands of smallholders with an extremely small average farm size of 0.3 ha due to a high population density (Morris et al., 2009) (IFDC, 2013). Rwanda has approximately 1.5 million smallholder subsistence farmers, more than 80 percent of whom cultivate less than 1 ha of land, about half cultivate less than half a hectare and more than a quarter cultivate less than 0.2 ha (IFDC, 2014). Other key features include:

**Hilly:** Rwanda is endowed with hilly and fertile land, As reported by the World Bank, farming the slopes is a toil, frequently pitting the will of farmers against erratic weather. Droughts can exact a heavy toll while heavy rainfall can wash away standing crops, erode soils, and damage hand-built terraces, pushing farmers deeper into poverty (World Bank, 2015).

**Primarily rainfed:** The crop systems remain largely rainfed with consequences on yields. It has an average annual rainfall level of 1,200 mm, which varies from 800 to 2 000 mm depending on the region<sup>40</sup>.

This results in a system of production that is still highly dependent on rainfall, which can be observed through the annual variations of the agricultural growth rate (see Figure 1). The volatility of rainfed is likely to be a problem for getting a steady increase in fertilizer use unless more water control is achieved. The years just after the genocide have been characterized by a peak in the agricultural growth rate followed by levels of growth rates of around 10 percent until the early 2000s.

38. World Bank. WDI. Current USD, Atlas method. Rwanda aspires to be a middle-income country by 2035; and a high income country by 2050. <https://data.worldbank.org/country/rwanda> - <https://www.worldbank.org/en/country/rwanda/overview>

39. Data are from WDI (Poverty headcount ratio at \$1.90 a day, 2011 PPP, % of population) and World Bank Rwanda Overview. Otherwise they are cited in the text

40. FAO AQUASTAT Country Overview

**Figure 1: Agricultural annual growth rate in Rwanda**

Source: FAOSTAT

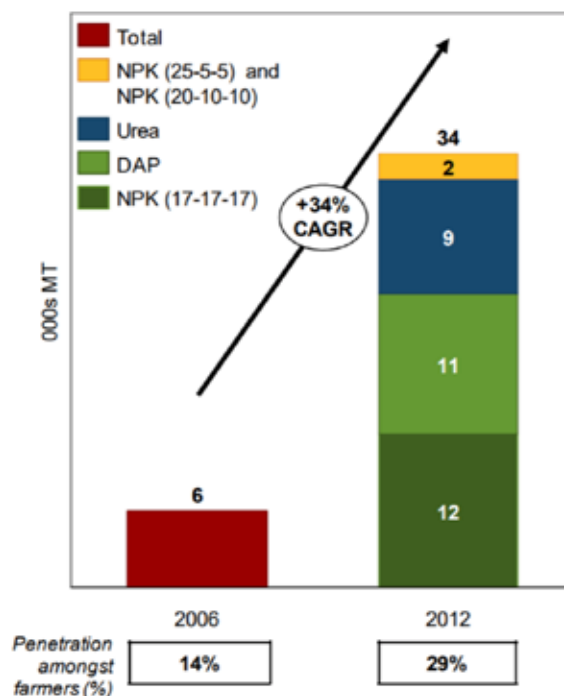
One percent annual growth in food crops generates 0.11 percent annual growth in the non-agricultural sector (Diao, 2015). An additional 2.6 percentage point growth of all sub-sectors combined, create 0.9 percentage point additional growth in non-agricultural GDP (IPAR, 2015). One USD of public spending in agricultural staples generates more than three times (3.63 USD) agricultural GDP and 0.21 USD of non-agricultural GDP (IPAR, 2015).

Rwandan leadership—Vision 2020 and related plans for agriculture: The Rwandan government set up Vision 2020 of which the major objectives are: Macroeconomic stability and wealth creation; Structural economic transformation; Creating a productive middle class and fostering entrepreneurship. One of the six pillars of this vision is entitled “Productive high value and market-oriented agriculture”, which clearly defines the government’s orientation for the agricultural sector. It aims to replace subsistence farming by a fully, commercialized agricultural sector by 2020 (MINECOFIN, 2012). The government implements a series of consecutive “Strategic Plan for the Transformation of Agriculture” (PSTA). The current PSTA-4 aims to achieve an average of 10 percent agricultural growth over the next six years (2018-2024); to raise irrigated farm area from about 50 000 hectares to 102 284 hectares in order to reduce reliance on rain-fed agriculture, raise productivity and resilience of crops systems, and then improve food security; to increase fish production from 27 000 metric tons to 112 000 metric tons by 2024.

The Crop Intensification Program—content and impact: Launched in 2007, the Crop Intensification Program aims to increase agricultural productivity of high-potential food crops by creating incentives for producers to adopt new production technologies, especially fertilizer, seed and irrigation, and to improve soil fertility. It aims at creating awareness of the benefits of using fertilizer among small farmers; using subsidy vouchers to promote and stimulate fertilizer markets; refining outdated technical recommendations; implementing regular quality control; implementing land consolidation; and providing credit facilities for fertilizer and seed buyers (MINAGRI, 2012) (IFDC, 2014). Partly due to these measures, Rwanda recorded a substantial increase in fertilizers consumption per unit of land, even if the current level is still below the Abuja Declaration’s target (50 kg per hectare). The average quantity of fertilizer used per cultivated hectare grew from 4.2 kg/ha to 29 kg/ha between 2007 and 2012 (Wanzala et al, 2013) (IFDC, 2017). Several analysts linked this performance with the Crop Intensification Program (CIP), which efficiently combines policies on key components: land, water,

seeds and fertilizers. However, since these four inputs constitute derived demand, market access also has a key role.

**Figure 2: Fertilizer Imports in Rwanda**



### Market access critical for fertilizer use

Market access a key factor in promoting fertilizer use: There is substantial evidence that the better the access to the end markets, the better are the incentives to raise production, and the higher is the – derived – demand for fertilizers and complementary inputs.<sup>41</sup> Important examples include:

- In Côte d’Ivoire, export crops represent the main part of fertilizer consumption. Cocoa and cotton are the two highest fertilizer consuming crops. In 2013, cocoa represented 29 percent of area harvested (FAO) but 44 percent of fertilizer consumption. (AfricaFertilizer.org, 2016). Cotton represented only 5 percent of total harvested area (FAO) but 40 percent of fertilizer consumption (AfricaFertilizer.org, 2016).
- In Kenya, the two highest fertilizer-consuming crops are maize and tea. Maize is the main crop with 36 percent of harvested area (FAO) and 53 percent of fertilizer consumption in 2013 (Argus, 2016). Tea is the first export product with 22 percent of total exports value in 2017 (OEC)<sup>42</sup>. It represented 3 percent of harvested area (FAO) but consumed 17 percent of total fertilizer quantity (Argus, 2016). In an older study by Hassan and Karanja (1997)<sup>43</sup>, they found that Kenyan farmers that grew tea and coffee, in addition to maize, used 5.5 kg more fertilizer on maize than those that produced maize without also growing a cash crop.

41. From an economic point of view, the demand of fertilizer is referred to as a “derived demand” because it is determined to a large extent by the final demand for the crop produced

42. Observatory of Economic Complexity

43. Cited by Reardon et al. (1999)

- In Burkina Faso, maize and cotton are the highest fertilizer consuming crops. Maize, which represented 13 percent of total harvested area (FAO), recorded 41 percent of total fertilizer consumption. Cotton, an export (cash) crop, represented 9 percent of harvested area (FAO) but 44 percent of total fertilizer consumption (AfricaFertilizer.org, 2016). After gold, cotton is the second export product of Burkina Faso (OEC)<sup>44</sup>.

Furthermore, in many sub-Saharan African countries, export (or cash) crops like cocoa, coffee, and cotton benefit from an interprofessional organization which enables farmers to enjoy better access to lucrative and more guaranteed end markets, as well as better access to appropriate inputs. Within countries for which these crops are important sources of export and government revenues, they benefited from more support from the government intervention through different forms of market participation.

Farmers' organizations also instrumental in increasing input use and forging market linkages: Farmers' organizations can be effective models for raising input adoption and use. In Rwanda, farmers who are organized into cooperatives have more market linkages. An analysis of market availability showed that 30.8 percent of African farmers do not have market linkages; this poor access is attributed to their non-grouping into cooperatives. Market availability varies within the provinces: Southern and Northern provinces in Rwanda have the least access to markets for agriculture produce. Eastern and Western have the best market linkages and do not have a problem in marketing their produce (Dusengemungu, 2013).

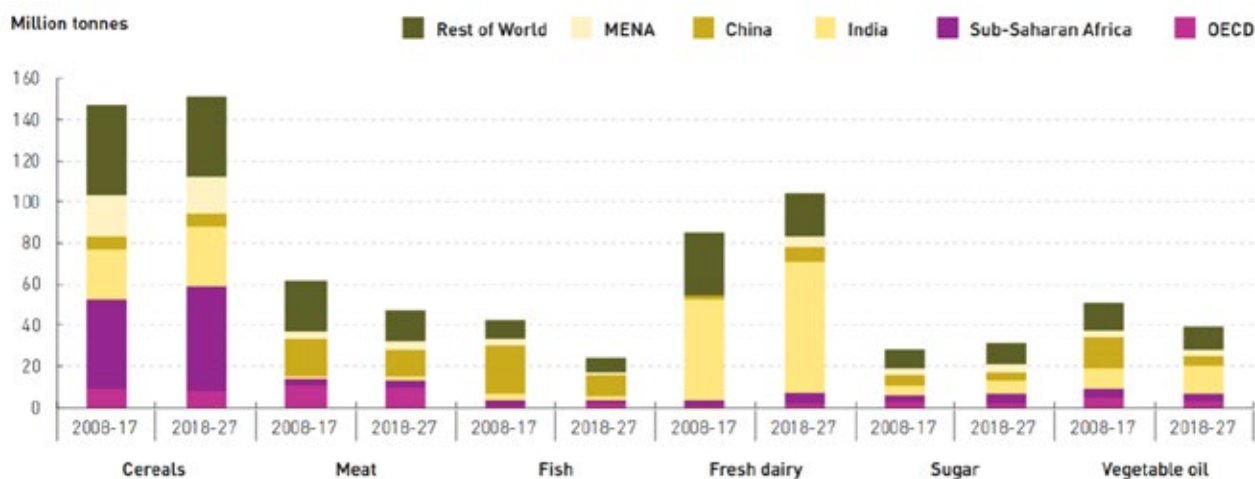
Access to increasing food market in Africa also a boost to fertilizer demand: Non-export crops (mainly staple crops) also experience improvements in market opportunities because of the growing local demand which is being driven by increasing population, urbanization, and improvements in the purchasing power and a reduction of costs of market access for farmers. In Ethiopia, around 85 percent of the fertilizers applied is used on three main crops: teff, maize and wheat. Around 35 percent of the fertilizers imported are applied on teff, 25 percent on maize and 25 percent on wheat (Argus, 2016). According to a report from USAID, the successful absorption of increased yields in rice and potatoes by a large domestic market, have demonstrated to the Government of Rwanda the impact that strong end markets can have on promoting agricultural productivity. (USAID, 2012); and thereby driving up the demand for fertilizers and complementary inputs. There have been instances in the cultivation of maize where farmers use too little fertilizer or divert the fertilizer to other crops like rice, potato, because end market demand for maize is weak (USAID, 2012) In view of this, the Government of Rwanda has learned that increasing agricultural productivity will only be successful if there are developed end markets to absorb the increased yields.

Promote fertilizer demand by improving access to expanding markets: These field level instances clearly illustrate the importance of access to lucrative and growing end markets in stimulating the willingness to improve productivity by use of more fertilizers. End markets may be either the international market or national or regional market. If these markets are well exploited, both food and cash markets would represent a huge opportunity to increase agricultural productivity and therefore stimulate the demand for fertilizers and complementary inputs. Figure 2 highlights the opportunity that represents the growing domestic food market in Africa. For instance, most of the increase of cereals demand in the world will come from sub-Saharan Africa.

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44. OEC: Observatory of Economic Complexity

**Figure 3: Regional contributions to food demand growth, 2008-17 and 2018-27**



Sources: (OECD and FAO, 2018)

### Water control, essential to complement fertilizer use

Importance of water control fully recognized by the CIP, among many others: Recent Rwandan experience also confirms the key role of irrigation. Irrigation is a main component of Rwandan Crop Intensification Program to which the recent important increase in productivity has been attributed to. The country has a national irrigation potential of nearly 600 000 ha, taking into consideration the following domains: Runoff for small reservoirs (125 627 ha), Runoff for dams (31 204 ha), Direct river and flood water (80 974 ha), Lake water resources (100 153 ha), Groundwater resources (36 434 ha) and Marshlands (222 418 ha)<sup>45</sup> The government developed the Irrigation Master Plan in 2010 with a potential total area for irrigation of 589 711 ha, now about 3 percent of the total identified area is irrigated in both the marshland (22 554ha), hillside (1 482ha), and other small-scale irrigated areas (100ha) (IPAR, 2015; MINAGRI, 2010). The critical importance of water control in Rwanda's experience is not unique. As stated by Drechsel et al (2015), improvements in nutrient use efficiency should not be viewed only as fertilizer management. Increased soil-water storage and availability to crop plants at critical growth stages improves utilization of fertilizer and other farm inputs (van Duivenbooden et al., 1999)<sup>46</sup>. Irrigation helps to regulate the supply of water to crops and increases the fertilizer use efficiency. Water and nutrient use within plants are therefore closely linked. Fertilizer use also affects water intake. Poor soil fertility limits the ability of plants to efficiently use water (Bossio et al., 2008)<sup>47</sup>.

The critical importance of water control a major challenge to Africa's GR: In sub-Saharan Africa, less than 5 percent of cultivated land is irrigated<sup>48</sup>. In sandy soils in southern Niger, rainfall determined the nitrogen fertilizer use efficiency and millet yield (Bationo et al., 1989). With low rainfall, nitrogen fertilizer did not affect the yield; with average or above-average rainfall, nitrogen fertilizer application increased millet grain yield fourfold to fivefold (Singh et al. 2015). Singh et al. (2015) noted that the

45. <http://www.worldagroforestry.org/downloads/Publications/PDFs/B16738.pdf>

46. Cited by (Singh, Ryan, Campbell, & Kröbel, 2015)

47. Cited by (Drechsel, et al., 2015)

48. [http://www.fao.org/nr/water/aquastat/tables/WorldData-Irrigation\\_eng.pdf](http://www.fao.org/nr/water/aquastat/tables/WorldData-Irrigation_eng.pdf)

application of even small amounts of water in addition to rain can lead to a significant increase in the crop yields in dry areas at high water use efficiency, provided other factors such as plant nutrient availability are adequate. Yilma et Berger (2006) concluded that the risk associated with rainfall variability was the most important determinant of fertilizer use. Irrigation has significant indirect effect on inorganic fertilizer use through its compounding effect on other variables. Under a climate change scenario of more frequent extreme weather events (e.g., droughts and floods) and greater variability in precipitation, increasing water control will become even more challenging. (World Bank, Africa Region, 2009: xviii)<sup>49</sup>

### **Land –access and security of tenure critical for smallholders**

Importance of land in farmer decision making is widely recognized: On one hand, access to land is usually a price and institutional related issue. Based on the theory of induced innovation, many authors showed that land price is an important determinant of demand for intensification practices and inputs such as fertilizers (Boserup, 1965; Ruthenberg, 1980; Hayami and Ruttan, 1985)<sup>50</sup>. On the other hand, the rhythm of transformation of customary institutions also affects the productive use of land. Social institutions affect conditions of access and patterns of resource use, like arable land (Berry, 1989). Risk associated with uncertainty of land tenure reduces fertilizer demand. If the farmer discounts heavily the future, that may lead to "soil mining" today and lack of use of long-run soil amendments (Reardon et al, 1999).

The Land Use Consolidation program, integral component of the CIP: One strength of the Rwandan agricultural policy is the Land Use Consolidation program, an integral component of the Rwandan Crop Intensification Program. Indeed, the Rwandan Ministry of Agriculture and Animal Resources (MINAGRI) implements a land use consolidation model whereby farmers in a given area grow the priority food crops defined by CIP (maize, rice, wheat, Irish potato, cassava, soybean and beans) in a synchronized fashion that will improve the productivity and environmental sustainability, while keeping their land rights intact. The consolidation of land use involves successfully rearranged land parcels to consolidate the use of farm holdings (MINAGRI 2011, 2012). Prior to the beginning of the agricultural season, farmers commit to participation in the program and agree to forego traditional intercropping techniques in favor of cultivating a single, government-approved crop in collaboration with neighboring farmers (Brown et al., 2017).

Specific features of LUC program: A consolidated site with standard norms should have at least 5 ha and one priority crop chosen by the District following the agroecological zone. Consolidated use of lands allows farmers to benefit from the various services under CIP such as efficient delivery of inputs (improved seeds and fertilizers), proximity of extension services, post-harvest handling and storage facilities, irrigation and mechanization by public and private stakeholders, and concentrated markets for inputs and outputs. (Dusengemungu, 2013) Although consolidation is voluntary, it is a pre-requisite for availing the benefits such as subsidized inputs under Crop Intensification Program. (MINAGRI, 2012)<sup>51</sup>

49. World Bank. Africa Region. 2009. Making Development Climate Resilient: A World Bank Strategy for Sub-Saharan Africa. Report # 46947-AFR - <https://openknowledge.worldbank.org/bitstream/handle/10986/3211/469470ESWWhitOt20100FullOvNoImages.pdf?sequence=1&isAllowed=y>

50. References cited in Reardon et al. (1999)

51. Please refer to (Dusengemungu, 2013) for an extensive description of the Land Consolidation process

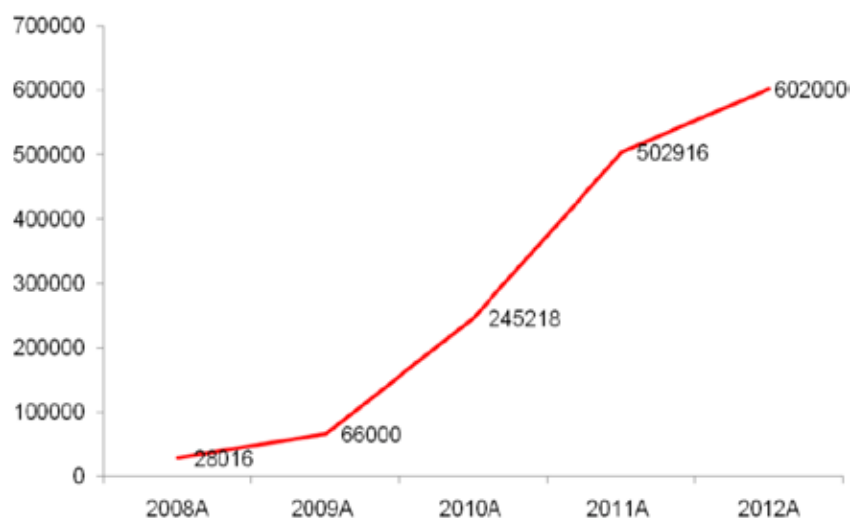
Land tenure –reform and security: Land tenure security is also at the core of Rwandan agricultural policy, viewed as a key contributor to farm-level investment and productivity.<sup>52</sup> The goal of the program was to increase agricultural productivity through the consolidation of land holdings and provide greater incentives to invest in agriculture, and thereby foster economic development (Gillingham & Buckle, 2014). In 1999, the Succession Law was adopted: it established equal inheritance rights for women and men (Daley et al., 2010). In 2004, the adoption of National Land Policy laid the foundation for land tenure reform. The 2005 Organic Land Law (OLL) outlined procedures for land tenure and titling, registering land and administering land titles, and providing guidance for land use and development (Gillingham & Buckle, 2014). The government also established an administrative structure for land administration. (Ali, Deininger, & Duponchel, 2016). The key operational features were:

- Implementation nationwide: the Land Tenure Regularization Program (LTRP) surveyed and issued titles for all individually-held land in Rwanda for the first time. From 2009 to 2013, the LTRP successfully registered 11.3 million parcels of land (98% of land parcels in the country). (Ali, Deininger, & Duponchel, 2016).
- The Government of Rwanda has taken steps to prohibit further land fragmentation and subdivision (Bizimana et al., 2004). The 2004 National Land Policy states that “the critical threshold below which a farmer can no longer meet his family’s basic nutritional requirements from agricultural activity alone is approximately 0.75 ha. Article 30 of the 2013 Land Law states that: “It is prohibited to subdivide plots of land reserved for agriculture and animal resources if the result of such subdivision leads to parcels of land of less than a hectare in size for each of them. Owners of lands prohibited to be subdivided shall co-own and use the land in accordance with the laws” (Kaiser Hughes & Kamatali, 2016); (Brown & Kaiser Hughes, 2017).

Substantial positive impact: The early effects of the program were notable: Land tenure security increased for both men and women, including women in de facto unions (Santos et al. 2014); the efficiency and functioning of land rental markets increased (Ali, Deininger, Goldstein, Ferrerara, & Duponchel, 2015a); and a basis for agricultural investment was established (references cited in Ali, Deininger, & Duponchel, 2016). Since the introduction of farm LUC in 2008, the total area under land use consolidation has increased by 21-fold from 28 016 ha in 2008 to 602 000 ha in 2012 (Dusengemungu, 2013) (see Figure 3). High adoption of appropriate agronomic practices is observed on consolidated sites while it is very low in the surrounding farms (Dusengemungu, 2013).

52. Brown and Kaiser Hughes (2017) provide an understanding of positive and negative impacts of land tenure security reforms in Rwanda. Applying a “secure enough” tenure framework, they conclude that despite increasing informality of ownership, land tenure in Rwanda is “secure enough” to incentivize smallholder investment in land, but that the emerging threats arising from the implementation of agricultural policies could constrain the country’s development gains in the future.



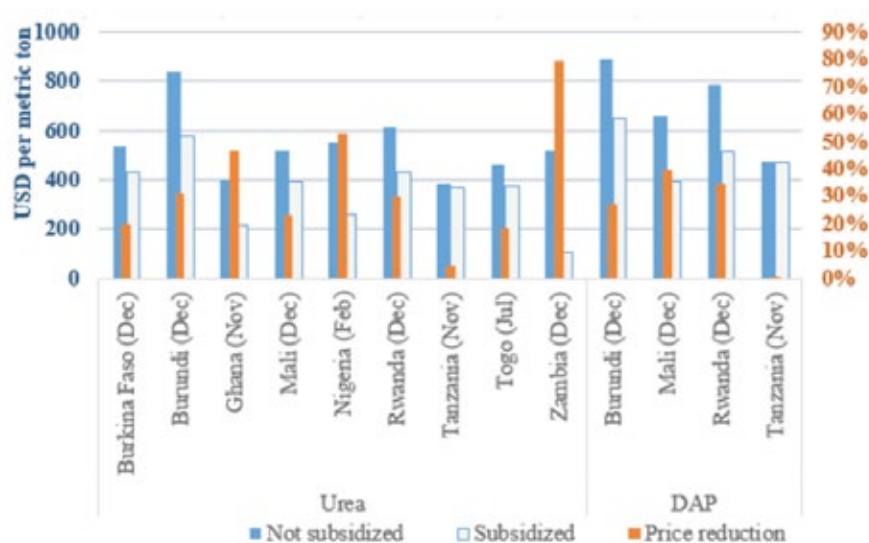
**Figure 4: Increase in LUC under priority crops in hectares**

Source: (Dusengemungu, 2013)

The consolidated production has also brought significant increases in food production –maize by 5-fold; wheat and cassava by about 3-fold; Irish potato, soybean and beans by about 2-fold; rice by 30 percent. The drive for consolidation of land use has a spiraling effect on the cultivation of priority crops as it indirectly promotes the use of inputs and extension services to farmers (Dusengemungu, 2013). LUC and associated production increase have significantly contributed to the poverty reduction in Rwanda for the past five years (NISR, 2012).

### **Last but not least: the price issue**

Fertilizer prices also matter: This paper focuses on market access on the output side, land and water on the input side. We consider these factors necessary for fertilizer use. But these factors are not enough. Obviously, the price level of the fertilizers supplied to the farmers have key role. Product prices can be decisive because, when making choices, farmers consider the relative cost of products in comparison to other inputs and factors of production. Indeed, farmers are sensitive to the relative price of outputs to that of inputs. Fertilizer prices should therefore merit careful attention. Guedegbe and Doukkali (2018) provided an overview of fertilizer prices' situation across the continent, the sources of the different price levels among and within countries, as well as policy recommendations in order to make fertilizers more affordable to African farmers. The supply price of fertilizer reflects inefficiencies in the markets along the chain and in transport conditions (including quality of transport and storage infrastructure). It emerges from the above analysis that the low consumption level of fertilizer in Africa is also attributable to often-excessive trading margins due to significant market distortions, inadequate infrastructure and under-used potential to produce and trade fertilizer within the continent. Figure 5 gives an overview of the variability of fertilizers prices among African countries.

**Figure 5: Subsidized and Unsubsidized Price of Fertilizer in 2017**

Source : AfricaFertilizer.org

Source: (Guedegbe and Doukkali, 2018)

### III. Towards a fertilizer policy for a productive and profitable smallholder agriculture in Africa: Principles and insights from Asia and Africa

To contribute to the debate on how best to promote sustainable soil fertility; in particular, the use of fertilizer (organic and inorganic) in smallholder agriculture of Africa, this concluding section draws upon key insights gained from the Asian experience, with focus on its two most populous countries: India and China;<sup>53</sup> as well as from the African experience, with special focus on Rwanda, a star performer. First, we present what in our view constitutes a “successful” fertilizer policy, in an age when environmental sustainability, in particular, the negative impacts of climate change, and resource degradation are major concerns; and when we consider that the benefits of sustained higher productivity and growth must benefit the majority, not just the wealthy few.

A successful fertilizer policy for smallholders promotes fertilizer use such that the following is true, namely:

1. The majority of smallholders use that level and mix of fertilizer such that they improve (at least, maintain) the fertility of the soils, a key foundation of agricultural productivity;
2. They benefit financially from doing so, because they can access profitable markets as the output/fertilizer price ratio is favorable;
3. Their use of fertilizer promotes sustained agricultural productivity growth (e.g., higher yields); as well as food supply and food security at national and household levels;
4. They use the fertilizer as part of a package of agricultural practices that is sustainable of basic

53. Total (United Nations) population estimates (billion) are: India: 1.37 (2019); China: 1.42 (July 2019); Africa: 1.32 (July 2019)

agricultural resources (e.g., in terms of soils and water); and is climate resilient;

5. In doing so for decades, smallholders promote an agricultural revolution (a Green Revolution (GR)), an economy-wide structural transformation, thus generating widespread income increases, poverty reduction and high income industrialization.

This concept of a successful fertilizer policy views fertilizer use as spearheading a sector-wide agricultural transformation which in turn is essential for widespread poverty reduction through economy-wide transformation.

Principles and major policy insights from Asia's Green Revolution, in particular that of India and China; and from agriculture in Africa, in particular, Rwanda.

Despite the major differences between the two continents—Asia and Africa, and among the three focus countries, it is striking that there is a robust pattern in terms of common principles and insights that should guide the formulation of a successful fertilizer policy for smallholder agriculture in Africa.

Leadership role of governments is key: Many Asian governments have successfully launched GR, and millions have benefitted in terms of greater grain supplies, and reduced hunger. However, the extent to which different Asian countries have spread GR and succeeded in utilizing fertilizer for realizing the above range of benefits has, of course, varied. However, one common denominator for launching the GR throughout Asia is the leadership role of governments. They made substantial and sustained investments as they sought to bring the GR input package—fertilizer, water, HYV seeds and pesticide—and improved market access together.

Delivering “the productive mix”—fertilizer, HYV seeds, pesticides, water, and lucrative market access, is demanding: Sustained government intervention and support was needed to bring together “the productive mix”. It is a politically, financially and administratively demanding task to bring about this mix, which is, after all, just the minimum. It is however more costly not to do so. How each government has tried to do so is necessarily different, which is to be expected given the vast heterogeneity of local circumstances, present and past. Two of the above items will be particularly challenging for Africa's leaders: water control and access to lucrative markets. Despite relatively abundant water resources, Africa has insufficient infrastructure to channel these resources for present needs. (World Bank, 2009: 2) Irrigation still accounts for 5 percent or so of cultivated land. With the dire predictions of climate change, Africa's vulnerability is deepening. Just expanding irrigation infrastructure is not good enough either as the operation and maintenance demands which bedevil India's system, in particular that of the State of Punjab, clearly show. With respect to market access, the dearth of infrastructure is still a major problem. “The region, which houses one seventh of the world's population, has a score of 2.91 in the infrastructure category of the World Economic Forum's (WEF's) Global Competitiveness Report.” (Calderon et al, 2018: 2)<sup>54</sup>

Long term nature of support needed by smallholders: It took decades of policy and institutional support for the GR launched in the mid-1960s to take root and spread in Asia. In a sense, the spread of new technologies to smallholders never ends; so that in many countries, the task is still ongoing. The critical support were the long term investments in public goods and services such as irrigation; transport and marketing infrastructure; and agricultural research and extension; and seasonal support

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54. The score index ranges from 0 (least competitive) to 7 (most competitive).

for private goods in terms of subsidized prices of fertilizer, HYV seeds and even the credit to purchase them. The long-term nature of support means that governments must balance the public and private nature of the goods and services they decide to subsidize. In particular, they must consider the financial sustainability of measures they use to promote fertilizer use. The seemingly intractable problem of reducing the financial burden of GR subsidies in India, at federal and state levels—consider the case of Punjab—is a cautionary tale.

Factors other than price subsidies also matter: While subsidies to purchase seasonal private production inputs were common, they were not always necessary as Mao's China shows: chemical fertilizer was promoted and its use increased substantially although it was taxed and was the entire agricultural sector to pay for industrialization. In addition, yields of most basic staples were high by international standards. Although one can argue that China is a "special" case, China's experience shows that in considering smallholder incentives to adopt new technologies, one must consider the entire socio-political environment and not just some piecemeal measures. Factors of particular importance have been the power of farmer traditions at grassroots level; marketing advantage of farmers' and other professional and interprofessional associations; and of leadership, local up to the highest level.

Farmer traditions: East Asian farmers have been using organic fertilizers for centuries. For forty centuries, "...judicious and rational methods of fertilization are everywhere practiced..." by the farmers of China, Korea and Japan... "manure of all kinds, human and animal, is religiously applied to the fields in a manner that secures an efficiency high above our own practices" (King, 2004: 9-11)<sup>55</sup> The process of transforming organic matter into usable fertilizer is very labor intensive but China is labor-abundant.

Inter-and Intra-professional organizations of farmers: In Africa, organizations of farmers in cotton, coffee, tea, and maize, provide an invaluable link for their members to their output and input markets. With their markets assured, the derived demand for fertilizer by these farmers are also some of the highest in Africa.

Leadership and vision—national and local: Although fertilizer was taxed, it was promoted vigorously by cadres who served as extension agents in communes. The power of their leadership was primarily derived from Chairman Mao himself to whom the superiority of collective agriculture was an article of faith; so showing it to be so, was patriotism itself. Mao's vision was however not a prosperous but a politically powerful China. Deng's vision was radically different: that of a prosperous Socialist China built on strong economic foundations.<sup>56</sup> The power of leadership is also evident in the Rwandan government promoting outstanding agricultural performance, after taking over a country which had endured the tragedy and trauma of genocide (1994).

Fertilizer use is not an end in itself but a necessary means to achieving a sustainable agricultural transformation: The experiences of India and China show clearly that increased fertilizer use is not always beneficial and therefore should not be considered an end in itself. In both countries, chronic

55. This book was originally published by Mrs. F.H. King under the name of *Farmers of Forty Centuries or Permanent Agriculture in China, Korea and Japan*, in 1911, Madison, Wisconsin. Franklin Hiram King (1848-1911) was a professor of agricultural physics at the University of Wisconsin-Madison.

56. Deng is reputed to have said: "It does not matter whether if a cat is black or white so long as it catches mice". This quote is often used to argue that Deng cared about actual results not just ideology. The complexity and greatness of Deng as a visionary and pragmatic leader is the subject of Vogel, Ezra, F. 2011 *Deng Xiaoping and the Transformation of China*. The Belknap Press of Harvard University Press, Cambridge, Massachusetts and London, England.

overuse has seriously undermined soil fertility and has degraded both soils and water. In the State of Punjab, the bread basket of India, with 95 percent of land irrigated, recent annual agricultural growth has slowed down, and yields stagnated (rice) and decreased (wheat and cotton).<sup>57</sup> Average application rate in China (kg nutrients/ha) is 428 versus 115 world average. China's NUE is low compared to world: estimated at 28 percent (2009) versus world at 47 percent (Heffer, 2016). Over the last three decades, China has been the fastest growing fertilizer market, with one of the highest average fertilizer application rates in the world. In the 2010s, it has accounted for some 30 percent of global fertilizer use. The overuse is evident when crop yields for maize, wheat and rice increased by 11 percent while fertilizer use were reduced by an average of 15 percent per crop. So, the farmers produced more with less! (Harris, 2018).<sup>58</sup> Professor Zhang Weifeng won the International Fertilizer Association Norman Borlaug Prize (2018) for steering Chinese farmers towards more efficient fertilizer use. (Farming First, Nov 1, 2018)<sup>59</sup> Such harmful overuse highlights the importance of promoting the education of farmers using fertilizer on best cultural practices by adequately financing extension services.

Land – access to and tenure security—of critical importance to smallholders: If fertilizer use is to serve as a means for achieving sustainable agricultural transformation, then smallholders' interest in the land they farm must take center stage. In addition to positive market incentives, access to and security of land tenure must be guaranteed as experiences of country after country clearly demonstrates. Important examples include:

In India, after two decades of land reform (late 1970s), landlessness was still widespread and land distribution remain skewed. The majority of smallholders have no tenure security. In eastern and central India which contain nearly 50 percent of net cultivated area, and 80 percent of India's rural poor (by the mid-1980s), high population pressure resulted in not only very small farms but also a high level of land fragmentation. (World Bank, Vol II, 1991: 19) So, India had the GR, but its agriculture is still not transformed. Indeed, the continued low growth and low productivity of Indian agriculture since the mid 1990s, and with food grains (World Bank Group, May 2014:8) still dominating, is a major source of concern. (World Bank, Nov 2017: 1)

In China under Deng Xiaoping, the transformative impact of the HRS was largely due to the fact that smallholder households obtained land tenure security for the first time. For the first time since 1949, smallholders were secure in their use rights to their most important production asset-land; and were able to profit fully from their hard work. Under Mao's regime, fertilizer use did substantially increase. But China's agriculture barely kept pace with the rapid population increase, though Mao's China wanted to "leap forward" not just barely survive. So Mao's China undertook redistributive land reform, but there was no land tenure security for farm households, and China experienced no agricultural transformation.

In Rwanda, the Land Use Consolidation (LUC 2008) program, an integral component of the Crop Intensification Program (CIP 2007) built on prior work of the National Land Policy (NLP 2004), the

57. During the 1990s, Punjab's agricultural annual growth performance slowed down to 2.6 percent well below the national average that rose to 3.2 percent with the crop sector growing at only 1.3 percent per year. TFP growth of the crop sector which averaged 2 percent in the 1980s virtually stagnated – at 0.05 percent per year during 1990-96. (World Bank, Sept 2003: vi, Tab 2.2, 2.3)

58. Harris, Briony. 26 March, 2018. "China cut fertilizer use and still increased crop yields. This is how they did it". World Economic Forum. (Accessed Nov 16, 2018) - <https://www.weforum.org/agenda/2018/03/this-is-how-china-cut-fertilizer-use-and-boosted-crop-yields/>

59. Farming First. Nov 1, 2018. "Professor Weifeng Zhang wins IFA Norman Borlaug Prize" - <https://farmingfirst.org/2018/11/china-agricultural-transformation/>

Organic Land Law (OLL 2005), and the Land Tenure Regularization Program (LTRP) which resulted in land surveys and the issuance of titles for all individually-held land in Rwanda for the first time. From 2009 to 2013, the LTRP successfully registered 11.3 million parcels of land (98 percent of land parcels in the country). Land tenure security increased for both men and women;<sup>60</sup> the efficiency of land rental markets increased; a basis for agricultural investment was established; all these developments contributing to Rwanda's star performance.

Decades ago, inclusive, agricultural transformation materialized in today's high income countries of South Korea; Japan; and Taiwan, China. In these three countries, land reform resulted in a uni-modal land distribution, which promoted a broad-based agricultural transformation and economy-wide industrialization.

Since Africa wants to promote an inclusive and sustainable Green Revolution; one in which fertilizer use is but one, albeit important component, then it is critical that its governments ensure their smallholders have access to land and tenure security. This is even more important as African youth are called upon to drive the GR. In fact, the Conference on Land Policy in Africa (CLPA2017) calls for precisely this.<sup>61</sup> The structure of land distribution; the status of land governance; and their key importance in Africa's development were extensively researched by UNECA in 2010. The World Bank's 2013 flagship report *Securing Africa's Land for Shared Prosperity* emphasized the same point.<sup>62</sup> It argued that poor land governance may be the root problem of Africa's chronic poverty. "The report offers a series of 10 steps for improving land governance that can help to revolutionize agricultural production and end poverty in Africa. With political will from African Governments and support from development partners, the plan to improve land governance in Africa in a decade could cost as little as US\$4.5 billion.

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60. In 1999, the Succession Law was adopted and established equal inheritance rights for women and men.

61. The Africa We Want: Achieving socioeconomic transformation through inclusive and equitable access to land by the youth - <https://www.uneca.org/clpa2017>

62. A 2013 World Bank report "Securing Africa's Land for Shared Prosperity," (Author: Frank Byamugisha, Lead Land Specialist, Africa Region) released on July 22, argued that poor land governance – the manner in which land rights are defined and administered – may be the root of the problem. <https://www.worldbank.org/en/region/afr/publication/securing-africas-land-for-shared-prosperity>

## APPENDIX

**Table 1: Key Structural Changes of India's Agriculture (1947 to 2010s)**

Item	Unit	Import-Substitution, High Trade Protection period (1947-mid 1980s)	Liberalization, Reduced Trade protection period (mid 1980s-2010s)	Year
<b>Land</b>				
Net cultivated land	Million hectares (m ha)		142.6	1990s
Irrigated land	m ha	21		1950
Irrigated land	m ha	42		1984/85
Irrigated land	m ha		57	1990s
Irrigated land	Percent of net cropped area		40	2000s
Arable land/man	Ha	0.34		1961
Arable land/man	Ha		0.12	2016
<b>Labor</b>				
Ag Lab/Tot Labor force	Percent	75		1947
Ag Lab/Tot Labor force	Percent	70		1981
Ag Lab/Tot Labor force	Percent	60		1980s
Ag Lab/Tot Labor force	Percent	60		2003
Rural Lab/Tot Labor force	Percent		49	2014
<b>Fertilizer</b>				
Fertilizer use	Kg/ha	5		1964-65
Fertilizer use	Kg/ha	62		late 1980s
Fertilizer use	Kg/ha		86	2001-02
<b>Agriculture share in GDP</b>				
AG/GDP	Percent	60		1947
AG/GDP	Percent	30		Late 1980s
AG/GDP	Percent		15	2017
<b>Trade openness and growth</b>				
Merchandise trade/GDP	Percent	12-19		1980-90

Merchandise trade/ GDP	Percent		20	1995
Merchandise trade/ GDP	Percent		25	2000
Merchandise trade/ GDP	Percent		30	2005
Merchandise trade/ GDP	Percent		40	2016
Merchandise export growth	Percent		17.5	2000-13
<b>Agricultural annual growth</b>				
AG GDP growth	Percent	2.6		1949-74
AG GDP growth	Percent		2.0	2013-15
AG GDP growth	Percent		3.7	1985-95
AG GDP growth	Percent		3	1970-2014
<b>Food grains</b>				
Food grains	Percent of gross cultivated area	90		1950s
Food grains	Percent of total cropped area	77		1970s
Food grains	Percent of total cropped area		66	2000s
<b>Rural:Urban ratio</b>				
Rural: Urban	Ratio	85:15		1950s
Rural: Urban	Ratio	82:18		1960
Rural: Urban	Ratio		69:31	2011
Rural: Urban	Ratio		66:34	2017
<b>Poverty</b>				
Extreme Poverty USD 1/day	Headcount ratio %	50		1980s
Extreme Poverty USD 1/day	Headcount ratio %		46	1990s
Extreme Poverty USD 1.90/day	Headcount ratio		25	2000
Extreme Poverty USD 1.90/day	Headcount ratio		15	2014



## Notes and Sources

- **Land** : (Chakraborty, 2003) ; (World Bank, 1991) ;
- **Trade** Openness and Growth: World Development Indicators; (World Bank, 2014)
- **Labor**: (Lele & Balu, 1994); (World Bank, 1991); (Pursell, Ashok, & Kanupriya, 2007); (World Bank, 2018)
- **Fertilizer**: (Srinivasan, 1994); (World Bank, 2003)
- **Agriculture's share of GDP**: (Srinivasan, 1994) ; (World Bank, 1989); (World Bank, 1991)
- **Agricultural annual growth**: (Economics and Policy Division, Agriculture and Rural Department (AGREP), World Bank, 1977); (World Bank, 2017); (World Bank, 2018)
- **Food grains**: (Bacon, 1956) The percentage is computed from raw figures on acreage cultivated under major crops (total food grains and total oilseeds) under the first Plan Period (1950/51 to 1955/56); (World Bank, 1977); (World Bank, 1999); (World Bank, 2014)
- **Rural:Urban Ratio**
  - » Government of India: <https://archive.india.gov.in/citizen/graminbharat/graminbharat.php>
  - » WDI: <https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS>
  - » Press Trust of India. New Delhi. July 15, 2011. "70 % of Indians live in rural areas: Census". (Updated Jan 20, 2013. Accessed Feb 20, 2019).
  - » [https://www.business-standard.com/article/economy-policy/70-indians-live-in-rural-areas-census-111071500171\\_1.html](https://www.business-standard.com/article/economy-policy/70-indians-live-in-rural-areas-census-111071500171_1.html)
- **Poverty**
  - » (World Bank, 1989); (World Bank, 2003)
  - » Wikipedia. Extreme Poverty. Last edited Feb 08, 2019. Accessed Feb 20, 2019.
  - » [https://en.wikipedia.org/wiki/Extreme\\_poverty](https://en.wikipedia.org/wiki/Extreme_poverty)

**Table 2: Key Structural features of Punjab's Agriculture (1980s-2000s)**

Item	Unit / Period	The State of Punjab
Net sown area	% of total India/ 2000s	3
Farming population	% of total India/ 2000s	1.5
Irrigated land	% of total sown area in Punjab/1990s	95
Cropping intensity	1990s - onwards	192
Crop sector	% per year growth/1980s	4.8
Crop sector	% per year growth/1990s	2.6
Rice & wheat	% of total cropped area/2000s	75
Rice	% contribution to India total/2000s	10
Wheat	% contribution to India total/2000s	20
Fertilizer use	Kg/ha/2000s	167
Pesticide use	Kg/ha/2000s	0.83
Cost of MSP & Grain Stocks	% GDP to the GOI/1990s	0.5
Cost of MSP & Grain Stocks	% GDP to the GOI/2002-03	0.8
Cost of all agric. input subsidies	% Agric GSDP of Punjab/2001-02	10.5

**Table 3: Key structural changes of China's Agriculture (1949-2010s)**

Item	Unit	Mao Centrally Planned period (1949-79)	Deng Transformation period (1980-2010s)	Year
<b>Land</b>				
Arable land	Million hectares (m ha)	137		1950s
Irrigated land	Million ha		45-67	1978-2016
Irrigated land	Percent of arable		40-50	2009
Arable land/man	Ha	0.16		1961
Arable land/man	Ha		0.09	2016
<b>Labor</b>				
Ag Lab/Tot Labor force	Percent	84		1952
Ag Lab/Tot Labor force	Percent		70	1981
Ag Lab/Tot Labor force	Percent		18.3	2015
<b>Fertilizer</b>				
Fertilizer use	Kgs/ha	22.5		1962
Fertilizer use	Kgs/ha		200	1980s
Fertilizer use	Kgs/ha		428	2000s
<b>Agriculture's share in GDP</b>				
AG/GDP	Percent	68		1949
AG/GDP	Percent		32	1988
AG/GDP	Percent		7.9	2017
<b>Trade openness and growth</b>				
Merchandise trade/GDP	Percent		60	2000s
Export growth	Percent		500	1990s-2000s
<b>Agricultural growth</b>				
AG GDP growth	Percent per year	2.2		1952-78
AG GDP growth	Percent per year		6.9	1978-84

AG GDP growth	Percent per year	4.5	1978-2016
<b>Food grains</b>			
Food grains	Percent of total sown area	87.2	1950s
Food grains	Percent of total sown area	79.2	1981
<b>Crop versus livestock</b>			
Crop versus livestock	Percent of AG GDP	82 versus 14	1970
Crop versus livestock	Percent of AG GDP	56 versus 30	2000
<b>Rural : Urban ratio</b>			
Rural : Urban	Ratio	90:10	1949
Rural : Urban	Ratio	84:16	1960
Rural : Urban	Ratio	49:51	2010
Rural : Urban	Ratio	42:58	2017
<b>Poverty</b>			
Extreme Poverty/ USD 1.25/day	Headcount ratio %	85	1981
Extreme Poverty USD1/ day	Headcount ratio %	40	1990
Extreme Poverty/USD 1.25/day	Headcount ratio %	27	2005
Extreme Poverty USD 1.90/day	Headcount ratio %	10	2014

### Notes and Sources:

The definition of agriculture in China comprises not only crops (annual and perennial) which dominate, but also forestry, livestock and fisheries.

- **Land:** (World Bank, 1988); (World Bank, 1991) Total arable land in China is 137 m ha; total area

of China is 960 m ha; arable/total: 14.27 percent; (Zhu, Yizhan, Mui, Yaozhong, & Peijun, 2013);

- **Labor:** (Perkins & Shahid, 1984); (Fang, 2018)
- **Fertilizer:** (Srinivasan, 1994); (Perkins & Shahid, 1984); (Heffer, 2016);
- **Agriculture's share in GDP:** (World Bank, 1991) ; WDI (respective year); (Huang, Scott, Martin, & Yu, 2007)
- **Trade openness and growth:** WDI
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  - » <http://documents.worldbank.org/curated/en/167191468236683844/pdf/wps4628.pdf>
- **Agricultural growth:** (Huang, Scott, Martin, & Yu, 2007); (Huang & Scott, 2018)
- **Food grains:** (Perkins & Shahid, 1984); (Findlay, 2005)
- **Crops** versus Livestock: (World Bank, 2012)
- **Rural / Urban Ratio:** (Srinivasan, 1994); WDI; (Simpson, 2012)
- **Poverty:** (World Bank, 2004) (Fig 2); (World Bank, 2009); (World Bank, Development Research Council of the People's Republic of China, 2013); Wikipedia. Extreme Poverty. Last edited Feb 8, 2019. Accessed Feb 20, 2019 ([https://en.wikipedia.org/wiki/Extreme\\_poverty](https://en.wikipedia.org/wiki/Extreme_poverty))

**Table 4: Key features of Rwandan agriculture**

Item	Unit	1990s	Post 2000	Year
<b>Land</b>				
Cultivated area	1 000 ha		1 402	2015
Irrigated area	1 000 ha		9.625	2007
As % of cultivated area	%		0.71	2007
Irrigated area	1 000 ha		17.679	2015
As % of cultivated area	%		1.26	2015
<b>Labor</b>				
Ag Lab/Tot Labor force	Percent	89		1995
Ag Lab/Tot Labor force	Percent		67	2018
Arable land/person	Ha	0.12		1995
Arable land/person	Ha		0.099	2016
<b>Fertilizer</b>				
Fertilizer use	Kgs/ha		2	2003
Fertilizer use	Kgs/ha		20	2015
<b>Agriculture's share in GDP</b>				
AG/GDP	Percent	50		1994

AG/GDP	Percent	29	2018
<b>Trade openness and growth</b>			
Merchandise trade/GDP	Percent	31	1995
Merchandise trade/GDP	Percent	52	2018
Export growth	Percent	25	2007-12
<b>Agricultural growth</b>			
AG GDP growth	Percent	16	1995-99
AG GDP growth	Percent	6	2014-18
<b>Food grains</b>			
Food grains	Percent of total harvested area	13	1995
Food grains	Percent of total harvested area	22	2017
<b>Rural/Urban ratio</b>			
Rural: Urban	Ratio	92:8	1994
Rural: Urban	Ratio	83:17	2018
<b>Poverty</b>			
Poverty headcount ratio at \$1.90 a day (2011 PPP)	(% of population)	77	2000
Poverty headcount ratio at \$1.90 a day (2011 PPP)	(% of population)	56	2016
<b>Agricultural productivity</b>			
Agricultural value added per worker	(constant 2010 US\$)	162	1994
Agricultural value added per worker	(constant 2010 US\$)	600	2018

Note: The table divides the – short – Rwandan experience in agricultural transformation in two periods. The 1990s period when the country was experiencing or was just emerging from the social crisis. And the post 2000 period when important reforms and agricultural development program and policies have been set.

**Sources of data:** WDI, otherwise indicated below.

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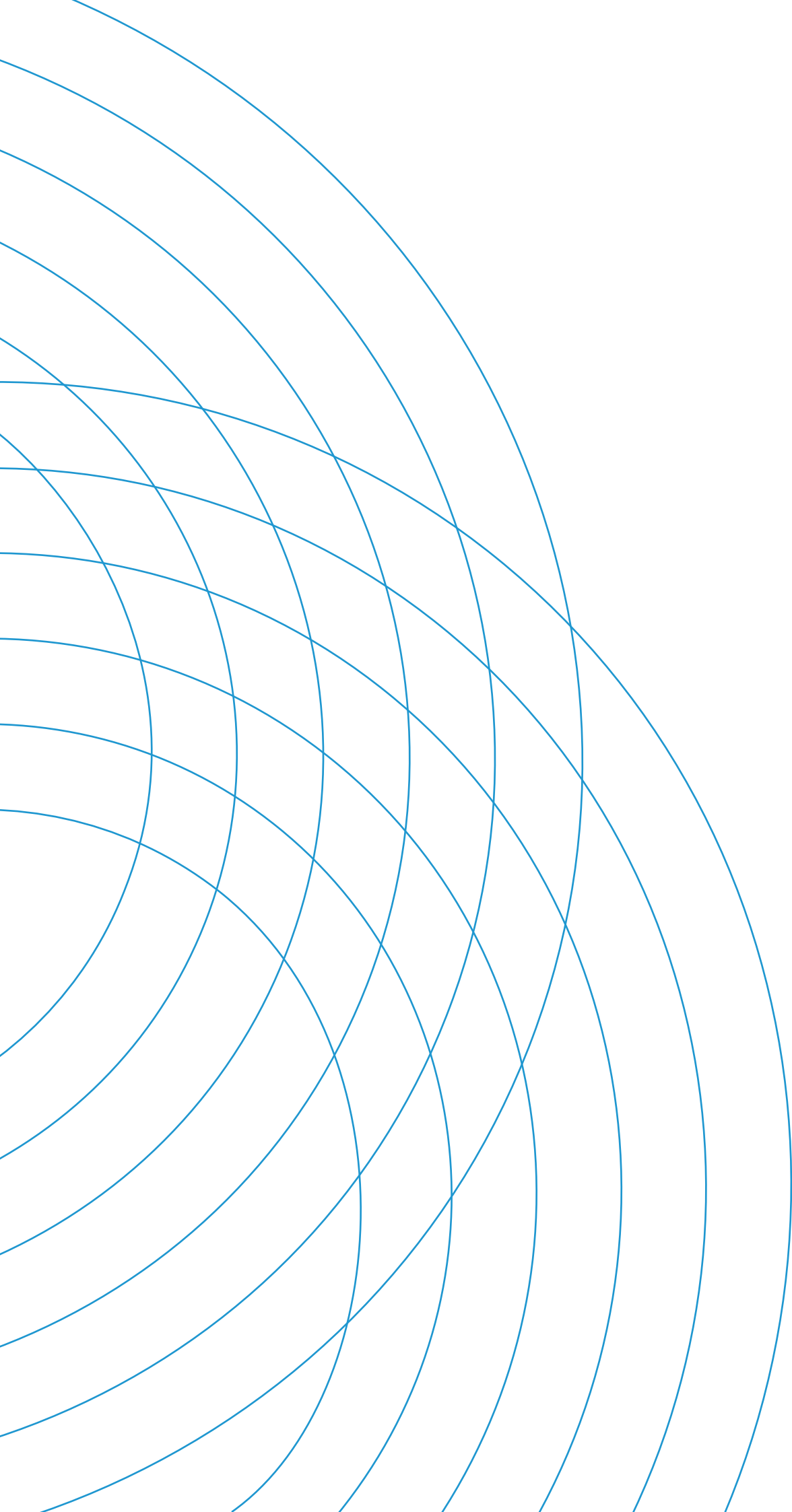
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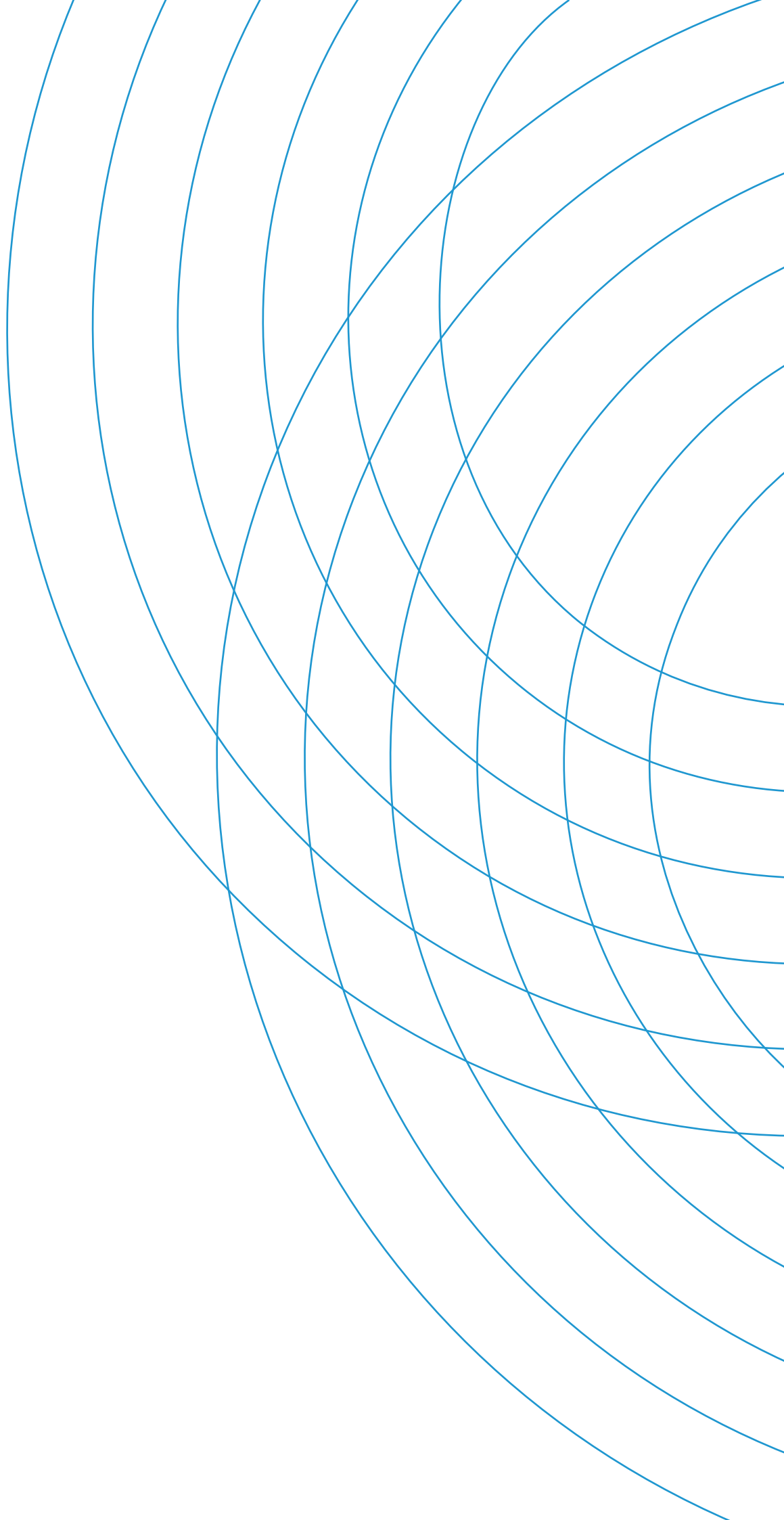
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Complexe Suncity, Immeuble C,  
Angle Boulevard Addolb et rue Albortokal,  
Hay Riad, Rabat - Maroc.

Email : [contact@policycenter.ma](mailto:contact@policycenter.ma)

Phone : +212 5 37 54 04 04

Fax : +212 5 37 71 31 54

Website : [www.policycenter.ma](http://www.policycenter.ma)