Production vs. consumption management for sustainable agricultural resources

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Abstract: At 35%, world food production wastage is jeopardising the sustainability of global resources and the future of food security, especially considering that agriculture uses 60% and 37% of the world water and land resources. Ironically, rural populations are most exposed to poverty and hunger when they feed the world. Through a literature review, this paper will demonstrate that supply management, based on consumption, is a solution to food wastage and can in parallel, improve rural wealth, introduce sustainable agricultural practices, resolve major urban pressures and bring about global climate change adaptation. The concepts presented in this paper confront modern world agricultural policies as production management systems are being abolished throughout the world, including Canada.

Keywords: sustainable resources; food wastage; climate change.


Biographical notes: Suzelle Barrington, PhD, Eng., Agr., has 44 years of experience with the primary food sector and its transformation industry, in designing facilities, mitigating their environmental impact and researching improved environmental technologies for organic waste and wastewater management. She held the position of Professor at McGill University for 26 years and, on a part time basis, International Research Chair with the Université Européenne de Bretagne for four years. She has travelled the globe as a consultant and speaker and this paper is based on her expert observations and analysis of agriculture across the world.

Bijaya Adhikari obtained a PhD from McGill University, Canada. His areas of specialisation include environment, waste and water resources management. He has published over a dozen refereed articles and presented research works in national and international conferences and seminars. He has several years work experience in the field of environment, waste management and water resources.
1 Introduction

While 35% of agriculture’s production is wasted globally if not more, rural communities around the world are faced with poverty and hunger, when ironically, they feed the world (FAO, 2013b). If agriculture is to continue feeding an ever increasing world population with the same soil, air and water resources, this wastage must be reduced and rural communities must be given the means to respect sustainable practices.

Sustainability is important in agriculture as it covers 37% of the globe’s land surface and consumes 70% of the world’s water supply. In terms of land usage, agriculture occupies 4.9 billion ha out of a world land base of 13.4 billion ha (FAO, 2013a). Within this 4.9 billion ha used by agriculture, 1.54 billion ha are cropped and 3.35 ha are under natural pasture or meadow. In 2010, agriculture still used 70% of the world water resources as compared to 10% for domestic and 20% for industry (Aquastats, 2015). In general, agriculture has a water use efficiency of 70% as compared to 14% and 10% for domestic and industrial usages (World Water Council, 2015). In terms of atmospheric gas emissions, agriculture is responsible for 10–12% of greenhouse gases (CH₄ and N₂O) and 70% of ammonia emissions (IPCC, 2007).

The objective of this paper is to propose a system capable of reducing food wastage to an achievable minimum of 5%; explain how this system can introduce sustainable measures in rural communities along with an acceptable standard of living, and; demonstrate its environmental, social and economic benefits. This paper will present the historical events and policies which have brought about the culture of food wastage; demonstrate how a supply management systems based on consumption, can reduce food wastage from 35 to less than 10%; identify conditions for the system to work, and; present the environmental, social and economic benefits. This paper is a policy recommendation based on a literature review and supported by the scientific knowledge of the main author acquired through 44 years of work in agriculture, around the world (Barrington, 2016). The concepts presented in this paper confront modern world agricultural policies as production management systems are being abolished throughout the world, including in Canada.

2 Literature review

2.1 Food wastage

According to Gustavsson et al. (2011), 35% of the world food production is lost, representing 1.3 billion tonnes/year. A compilation of statistics presented in Table 1 shows at least 25% food production exceeding world demand as in 2007, the average reported food intake of the world population was 2710 kcal, compared to a food
Production vs. consumption management

production after harvest of 3320 kcal. This 22% overproduction does not account for losses in the field as a result of poor market conditions or aesthetic reasons. Furthermore, Table 1 is a compilation of only the major food produce.

Table 1  World food production vs. consumption

<table>
<thead>
<tr>
<th>Continent</th>
<th>NA</th>
<th>CA</th>
<th>SA</th>
<th>Europe</th>
<th>Africa</th>
<th>Asia</th>
<th>Oceania</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population millions</td>
<td>344</td>
<td>156</td>
<td>393</td>
<td>738</td>
<td>4164</td>
<td>1022</td>
<td>36</td>
<td>6853</td>
</tr>
<tr>
<td>Food intake (kCal)</td>
<td>3500</td>
<td>2850</td>
<td>3000</td>
<td>3500</td>
<td>2600</td>
<td>2200</td>
<td>2800</td>
<td>2712</td>
</tr>
<tr>
<td>Food production (kCal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td>6180</td>
<td>537</td>
<td>322</td>
<td>1395</td>
<td>1529</td>
<td>1033</td>
<td>857</td>
<td>1579</td>
</tr>
<tr>
<td>Fruits and vegetables</td>
<td>182</td>
<td>304</td>
<td>318</td>
<td>214</td>
<td>233</td>
<td>161</td>
<td>318</td>
<td>224</td>
</tr>
<tr>
<td>Meat</td>
<td>1443</td>
<td>533</td>
<td>945</td>
<td>1062</td>
<td>349</td>
<td>180</td>
<td>2195</td>
<td>504</td>
</tr>
<tr>
<td>Oils</td>
<td>834</td>
<td>157</td>
<td>1726</td>
<td>499</td>
<td>310</td>
<td>67</td>
<td>298</td>
<td>386</td>
</tr>
<tr>
<td>Sugar</td>
<td>231</td>
<td>370</td>
<td>1180</td>
<td>279</td>
<td>130</td>
<td>97</td>
<td>1314</td>
<td>218</td>
</tr>
<tr>
<td>Roots and tubers</td>
<td>100</td>
<td>30</td>
<td>179</td>
<td>211</td>
<td>110</td>
<td>332</td>
<td>167</td>
<td>156</td>
</tr>
<tr>
<td>Pulses</td>
<td>160</td>
<td>90</td>
<td>78</td>
<td>58</td>
<td>52</td>
<td>103</td>
<td>167</td>
<td>156</td>
</tr>
<tr>
<td>Nuts</td>
<td>149</td>
<td>34</td>
<td>41</td>
<td>16</td>
<td>104</td>
<td>164</td>
<td>24</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>9279</td>
<td>2055</td>
<td>4789</td>
<td>3734</td>
<td>2817</td>
<td>2137</td>
<td>5340</td>
<td>3323</td>
</tr>
</tbody>
</table>

Cereals exclude that used to feed livestock; meat include milk and eggs; only major oils are considered, such as soybean, olive and palm; nuts include tree nuts and peanuts; the values in this table were computed from statistics available from FAO (2013a).

NA: North America, CA: Central America; SA: South America.

Tunisia offers a good example of food losses as a result of aesthetic reasons, where some 45,000 tonne of dates are not harvested, on an annual production of 113,000 tonnes (25% wastage), because of poor colour and appearance (Trigui et al., 2010).

A world compilation of food production and wastage (FAO, 2013b) indicates that the highest losses are associated with cereals at 26%, followed by vegetables at 24%, starchy roots at 18%, fruits at 16%, milk and eggs at 17.5%, meat at 4% and finally oilcrops and pulses at 3%. Globally, production and postharvest result in 54% of the food wastage, processing and distribution result in 25% of food wastage and finally, consumption results in 21% of food wastage. In Europe, North America, Oceania and Industrialised Asia (China, Japan, South Korea), 33% and 45% of food wastage occurs at the consumer and production/post-harvesting levels, as compared to 10% and 64%, respectively, for the rest of the world. This clearly demonstrates that food has little value for industrialised countries whereas, elsewhere, food production marketing and post-harvesting are the major causes.

Interestingly enough, meat (excluding milk and eggs) is the produce which suffers the least wastage, likely because it is considered a luxury item. Among all meat productions, cattle play a major role in sustaining world food supply by using natural meadows and...
pastures which account for 66% of all agricultural land and would be otherwise unused. Furthermore, in countries such as Ethiopia, cattle play a major role in feeding the population (Barrington, 2016) with minimum storage. Cereal crops harvested every six months can only be stored for three months, considering climatic conditions. On the other hand, cattle are fed from the straw and stalks left behind after harvesting cereals and from road side growth and are slaughtered one at the time, as needed. Mono-gastric livestock, such as poultry and pork, cannot be raised from such residues as they consume only cereals and compete for the human cereal supply.

2.2 Factors explaining unsustainable agricultural resources

While several historical factors have encouraged the present situation of world food surplus, the common end result was a price at the farm which does not justify sustainability both in physical and human resources.

Worldwide, agricultural development became a priority after World War II as acute food shortages persisted after hostilities especially in the continents which suffered destruction, namely Europe and Asia. A series of drought in 1946 and 1947 worsened the problem in the USSR, North Africa and the Far East. Only countries like Canada, the USA, Australia and Argentina could offer assistance, having been spared from war destruction (FAO, 2000). Furthermore, technological developments introduced during World War II, now offered agro chemicals, such as fertilisers, with the capability of increasing agricultural yields (UN, 1987). Wide spread world hunger and new agricultural technologies have brought governments to push for more food production, a growth reaching full speed in the early 1980s, surpassing population growth and creating major world surpluses along with stationary commodity prices at the farm till 2005 (FAO, 2000).

Still used today, several main concepts were introduced during the late 1940s with a major impact on agricultural sustainability: cheap food policies at the expense of agricultural producers and the sustainability of their resources; food and fibre production publically subsidised to boost agricultural production without supporting the full cost; food aid policies encouraging countries with surpluses to flood international market, and; the belief that low food prices would prevent poverty and hunger when the poor population was victim of such low farm commodity prices.

In the late 1940s, rapid industrialisation was introduced to solve post World War II economic issues, but it created in many cities, a large class of factory workers exposed to social hardship. Politically introduced, low food prices were designed to reduce such hardships but at the expense of the rural sector. Public financing of food and fibre production encouraged specialised farms without supporting the full cost. Underpaid for their produce, farm producers were easily enticed into such specialised productions without understanding the full financial implication. The world became aware of poor agricultural sustainability only 20 years later when the United Nations started to host conferences on issues such as soil degradation and erosion (FAO, 2000). Policies failing to support agricultural sustainability have persisted even today, with too low a number of farm producers to impact political decisions, and too large an urban population disconnected from agriculture but insisting on a continued supply of high quality but low price food items.

The unstable political climate of the 1950s, resulting from the cold war, and many African and Asian countries gaining independence, also brought about unstable
agricultural markets and disparity in world food supply. The United Nation’s Food and Agriculture Organisation (FAO) therefore advocated disposal of food surpluses to feed hungry countries across the world, thus not disrupting agricultural markets.

In the 1960s, the world had finally understood that research and knowledge dissemination were key to agricultural development. Research centres initiated in the late 1940s were finally proving their impacts (FAO, 2000). The introduction of new varieties made it possible to increase cereal yields throughout the 1960s and 1970s. From 1964 to 1984, world food production increase by 12% with 30% less land but with a 3-fold increase in fertiliser usage (UN, 1987). At the same time, many countries around the world had recovered from World War II and were able to afford more meat, milk and egg products. While prices at the farm did not change much, retailers tripled their sale prices especially for meat, taking advantage of the fact that such products were considered luxury items.

Furthermore, many developing countries, such as in Africa and Asia, took advantage of such high yielding varieties, thus producing local surpluses to export at the expense of sustainable practices. Today, many regions of Africa suffer from soil degradation: high yielding crops have depleted soil nutrients and organic matter because farmers did not have the financial means of buying the necessary fertiliser and of using the proper crop rotation practices.

In the 1970s, unfavourable weather conditions reminded the world once more of the fragility of the global food production system while a major increase in petroleum prices impacted the price and therefore the use of fertilisers. As a matter of fact in the early 1970s, world politicians were convinced that by the year 2000, population growth would surpass food production and there would be a global famine (Barrington, 2016).

A major world player, China introduced in the 1960s its ‘Great Leap Forward’ policy as a result of 23–30 million people dying of hunger following natural disasters of drought, typhoons, floods and insect infestation. This policy took effect in the early 1980s, when its industries could supported the development of its cereal agriculture (Zhu, 2012).

The early 1980s marked a worldwide economic recession in parallel with unsurpassed food production and international dumping. Countries like China and the USSR began exporting food produces whereas they had been major importers in the past. Although a long time food exporter, Brazil’s production of corn and soybeans was substantially increased for additional national wealth without necessarily introducing sustainable measures (Pereira et al., 2012). Although policies of cheap food supply had disadvantaged agriculture even in industrialised countries from 1945 to 1985, conditions deteriorated further in 1985 with a recession and countries such as China and the USSR starting to export agricultural products generating major international surpluses. Accordingly, the recession forced government cut backs and, faced with surpluses, agricultural subsidies were targeted. Furthermore, surpluses prevented any increase in commodity prices at the farm from 1985 to 2005 despite inflation in the cost of seed, fertilisers and machinery (Figure 1).

From 1990 to present, farm enterprises have been the victim of their own success. Some price fluctuations were observed over the years, as affected by unfavourable climatic conditions, but abundance gave the impression of food security. With all kinds of produce on store shelves all year around, urban populations became even more disconnected from agriculture. As economic conditions deteriorated for most rural communities, victim of revenue losses from government induced food surpluses, world
food aid encouraged even more dumping (FAO, 2000). The GATT did attempt to introduce policies to stop food produce dumping on the international market, but with limited success.

Figure 1  (a) Farm market price for grain corn in Ontario, Canada, vs. inflation since 1975 and (b) market price for fed steers in Iowa, USA, vs. inflation since 1975

In parallel with the drop in profit at the farm, employment also dropped sharply in the early 1990s even in developed countries while education remains mostly at or under secondary school level. In 2016 for example, almost 60% of Canadian farm workers have no more than a secondary level education and their annual salary, under 20,000$, is within the poverty margin (Service Canada, 2016). The situation is worse in the USA, with only 7% of all farm workers having completed their secondary schooling (National Farm Worker Ministry, 2016; Student Action Farm Workers, 2016). In developed countries, farm workers were excluded from labour laws from the very beginning. In the USA, the Fair Labour Standard Act of 1938 was finally amended in 1978 to establish minimum wages for agricultural enterprises, but overtime pay was never enforced and 12
years was set as the minimum age, as opposed to 16 everywhere else (Student Action Farm Workers, 2016).

Since World War II, policies worldwide have fundamentally exploited natural resources including those used for agriculture, in favour of industrialisation initially to recover from World War II, and later to improve living standards globally. International surpluses resulted from cheap food policies introduced in the late 1940s to solve starvation issues around the world. The result is a modern world population taking agriculture for granted, by not only wasting at least 35% of its production but by depleting the same world resources which guarantee food security. Today, politicians still believing that cheap food prices protect from hunger the lower classes when ironically, it is this same lower class, mainly in rural areas, which is starving from a lack of revenue created by such policies. The answer to sustainable resource management for food safety is: a reduction of food wastage from 35% to 5% by controlling surpluses, and; improved prices at the farm supporting a higher life standard, better educated farm personnel and sustainable practices. In summary, policies are required to control surpluses for sustainable practices and future food security while correcting the degraded management capability of farm producers. In Canada, the dairy milk quota system has proven capable of solving these issues.

3 Resolving the food wastage issue

Historically, the famines of the 1940s, 1960s and 1970s have pressured government to push so hard for greater agricultural production, that by the 1980s, agriculture’s growth impetus surpassed that of the world population resulting in major surpluses and the degradation of commodity prices at the farm from 1985 to 2005. Although commodity prices have improved at the farm since 2005, their increase has been too sporadic and their fluctuation has created disparity among production sectors. While at the farm commodity prices remained flat for 25 years, equipment and structures climbed with inflation by a factor of 10 (Figure 1). To survive, farm operation in developed countries has grown in size for improved efficiency resulting in higher surpluses. Furthermore, world resource sustainability has received little priority: from the transformer’s point of view, the produce is cheap and wastage does not affect profit, while; from the producer’ point of view, the low price at the farm does not provide the necessary funds to resolve issues related to environment and sustainability. A free trade system makes it impossible to control production when millions of producers are involved.

3.1 History of Canadian milk quota system

Production vs. consumption management is a quota system introduced in Canada following many attempts initiated in the 1960s to control the surplus production of milk which was costing to be dumped on international markets (Canadian Dairy Commission, 2016). Since then, the Canadian Dairy Commission and dairy producers’ associations have controlled production to match consumption and to maintain buffer stocks. In the early 1970s, each Canadian dairy farmer was given the right to produce milk in a quantity proportional to their production but adjusted to domestic consumption. Since then, dairy farmers have sold or bought quota, as their production capacity changed. Also, the Canadian Dairy Commission added and removed quota, proportionally among producers,
as consumption fluctuated. Dairy producers are paid for their milk based on a cost of production formula including funds to improve product quality and resource sustainability. The cost of production formula was so effective in encouraging efficiency among producers that Canadian dairy cows are among the most productive in the world (Barrington, 2016).

Early on, government support was removed and the dairy industry has been free of any subsidy for over 40 years. In parallel, all transformers were also given a transformation quota and a reasonable market price ceiling to protect the consumer. In Canada today, the store shelf price is shared equally among producers and transformers.

Canada instituted a quota systems only for perishable produce easily controlled domestically, such as for milk, eggs and poultry. Although still a matter of debate, this system has benefited producers, transformers and consumers as it provided a consistent marketing potential free of speculation, for a system with thousands of producers.

3.2 The quota advantage for consumers, producers and transformers

Historically, the dairy quota system in Canada had led to high quality production, with less than 5% wastage, more sustainable practices and a reasonable farm salary controlled by a cost of production formula based on efficiency.

For the consumer, the milk quota system means a more constant price at the grocery store free of any government subsidy. In 2014 with the Canadian dollar equal to that of the USA, a litre of milk was costing $1.86 at the grocery store, as compared to $1.40 in the USA. Nevertheless, USA dairy farmers received that year some $20 billion in direct subsidy excluding the government administration cost. Thus, the true price of one litre of USA milk was $1.90. Furthermore, Canadian dairy farmers are required to produce higher quality milk free of feed additives, and be sustainable such as properly storing manures and practicing soil nutrient management. Overall, the US litre of milk costs much more than $1.90 when considering the environmental impacts of the industry on water, soil and air quality.

The consumers have benefited from an equitable price for milk in the grocery store, without paying more, simply because the middle man’s profit margin was eliminated. From 1985 to 2003, Figure 2 shows how the indexed milk price dropped in Canada and France (with a quota system) while in other countries, the index price fluctuated and remained higher. Under a quota system, the price of milk is protected from market fluctuations and speculation because of a constant supply. The price of beef contrasts sharply with that of milk. This farm commodity price evolved slowly (Figure 1(b)) and rare herd level fluctuations because of poor prices, led to short price hikes dropping back to the previous level. In contract at the grocery store, prices increased with inflation and hiked along with those at the farm, but never dropped thereafter to their previous low at the expense of the consumer (United States Department of Agriculture, 2015). Grain price is another example where in 2012, poor climate conditions caused exaggerated speculations in world stock markets to the point that FAO interfered, to prevent famine in many parts of the world (Barrington, 2016).

Compared to their USA neighbours, Canadian dairy farms under a quota system enjoy better production conditions leading to higher quality produce subjected to less feed additives. As compared to 15% in the USA and in Canada for produce not managed by a quota, Canadian dairy farmers share 50% of the grocery store price. After bread,
meat is perhaps the produce with the highest profit margin for the wholesaler and retailer, at the cost of the consumer. Canadian dairy farm infra-structures, such as barns, are better insulated for a more efficient milk production requiring less feed and of higher quality because of a cleaner environment. In the long run, lower feed costs pay much more than the higher building costs. Barn insulation requires less resources for a ‘greener’ practice. Greater revenue security allows Canadian dairy farmers to obtain long-term financing for better infra-structures.

Figure 2  Index milk price at the grocery store, based on 1980 price. The price does not reflect direct government subsidy paid to the farmer, such as in the US.

Canadian dairy transformers have benefited from the milk quota system because of a guaranteed steady price enabling more accurate financial forecasting and profitability. For this reason, two important Canadian transformers have used their strong financial status to purchase plants worldwide and to take advantage of a larger market. Such Canadian transformers have also observed less milk wastage in Canada as opposed to other countries, and this both at the farm and at the plant. Canadian transformers operating plants in the USA observed raw milk wastage as a common practice also creating wastewater treatment issues, whereas in Canada, milk wastage is limited to returned product at about 1–2% of the total production (Barrington, 2016). This further challenges transformers to assure a longer shelf life for their produce, thus limiting store wastage. A Canadian 2% milk wastage compares quite favourably against 17.5% for milk and egg wastage worldwide (FAO, 2013b).

The general population has benefited from quota systems. Improved farm profitability and environmental incentives have encouraged good stewardship among Canadian dairy farmers. In terms of the lowest environmental footprint computed from energy consumption, water usage and greenhouse gas emissions, Quantis et al. (2012) report that Canadian dairy farmers are in second place after Great Britain and despite the use of insulated barns. In terms of soil conservation and nutrient management, Canadian farmers are among the most proactive, whereas many countries are still trying to balance nitrogen (Barrington, 2016).
3.3 Success conditions for production management systems

To be successful, a production management system must be supported by a government body monitoring production, controlling buffer stocks, regulating the industry and the producers. Conditions for produce quality and sustainability must be imposed by authorities along with a cost of production formula supporting such practices. Finally, producers must be supported technically to be able to implement such practices. This implies providing the technical support of field experts and the proper education of farm personnel, namely its managers and employees. Accordingly, the successful implementation of a production management system requires preparation time, depending on the intellectual capability of the farming community and the capability of the government to institute technological support.

Introducing a production management system could be initiated among a willing group of countries around the world, favouring before all, the local sale of domestic food products. Imports would be encouraged for out of season produce and under conditions of deficiency. This could drop energy consumption by 10% in world developed countries, as will be demonstrated later. With time, this group of countries could be expanded. The institution of a common at the farm commodity price would in parallel foster a common standard of living, a goal sought by FAO and the United Nations.

This production management system will be challenged as is the Canadian milk quota system. The issue is the misunderstanding that the general public has for agriculture, and the ignorance that a quota system eliminates all price speculation. In the USA along the Canadian border where most Canadians live, the price of milk at the grocery store is much lower to attract Canadian with a ‘lost litre of milk’. This is easily achieved as US transformers have a much higher share of the sales price at over 70%, as compared to 50% in Canada. Accordingly, the Canadian consumer has always felt that the Canadian milk quota system was overprotecting milk producers. Furthermore, the right to produce has become quite expensive in Canada over the years, as milk production became more and more attractive as compared to other agricultural sectors where farm commodity prices did not follow inflation. This issue was solved by placing a ceiling on the cost of quota.

4 Environmental, social and economic benefits

Solving the food wastage issue by introducing a production vs. consumption system would not only have a major impact on food safety but would also improve world environment such as resource sustainability and greenhouse gas production, living standard for a major percentage of poor people around the world and climatic change adaptation.

4.1 Environmental benefits

The environmental impact of 35% food wastage brings about the unnecessary use of resources and the release of elements in water and the atmosphere, besides soil degradation. Agricultural water wastage is mainly associated with irrigation practices, as this water is evaporated and no longer available for other uses (FAO, 2013b). In 2007, the
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Annual water losses through irrigated wasted food was 250 km\(^3\) (FAO, 2013), as compared to 185 km\(^3\) used by urban areas worldwide (McDonald et al., 2014).

Agricultural soil degradation is another serious preoccupation (EDL initiative, 2014). Annually, 24 billion tonnes of fertile arable soils are lost by soil erosion, representing an equivalent loss of 12 million ha of agricultural soils with 200 mm of arable soil. Although such a rate leads to the degradation of only 0.09%/year of the world agricultural surfaces, such practice has led to the degradation, salination and desertification of about 24% of world agricultural soils, leading to an equivalent amount of land deforestation. Furthermore, such river sedimentation has a major impact on the quality of the drinking water used by over 66% of the world population (McDonald et al., 2014), besides loosing costly nutrients and soil organic matter supporting land productivity.

In Africa for example, soils have been heavily exploited since the 1970s without replenishing their mineral levels (SSSA and ASA, 1997). In the early 1960s, high yielding crops were introduced to feed the growing population, without complimentary fertiliser applications, leading to the depletion of 200 million ha of agricultural land, providing a living for one billion people. If profitable at-the-farm prices were introduced in Africa, these soils could be enriched not only for nutrients but also for organic matter, and their productivity could be doubled. In parallel, rural populations could be educated to use more sustainable practices such as biogas generation rather than wood burning. In Ethiopia, wood is currently used as fuel, resulting in high atmospheric particulate levels and forest depletion.

Reducing food wastage from 35 to less than 10% would likely reduce pesticide and fertiliser usage by 20%, considering that such a practice is not affordable in some countries. Resulting from the use of soaps, the poor treatment of domestic sewage and the erosion of agricultural soils, developed countries are fighting surpluses of phosphorous in water resources when phosphorous mines are being depleted.

Finally, rotting wasted food leads to the emission of greenhouse gases and global earth warming trends. When compared to the greenhouse gas emissions of countries around the world, food wastage comes third producing 3.3 Gtonnes of CO\(_2\) equivalent, after China and the USA, at 7.2 Gtonnes and 6.9 Gtonnes of CO\(_2\) equivalent, respectively (FAO, 2013b).

In-the-field food wastage can lead to major indirect impacts. In 2004, an over production of tomatoes was observed in Central Western India, as a result of high prices during the previous season. While tomatoes produced from irrigation were being left in the fields and their irrigation along with a dry spell had exhausted water storage tanks, the urban population relied on the government of India to transport drinking water (Barrington, 2016).

4.2 Improving rural socio-economic status

A production vs. consumption system would introduce means to provide a specific level of farm profitability, determined by a pricing formula based on the price of supplies, equipment and property value, and on accepted sustainable and environmental practices. The living standard of the rural population would be improved, allowing for improved post-harvest technologies, thus reducing risks of not only wastage, but also starvation in many regions of the world ironically for those producing the food supply. It has been demonstrated that improving the production efficiency in rural areas has a major impact
on declining poverty and reducing rural migration towards urban centres (World Bank, 2015).

Besides reducing poverty, there is a major opportunity in empowering the rural population and improving not only its welfare, but its education, entrepreneurship and speed of adapting new technologies. Poor economic growth has led to the ‘in-breeding’ of rural population with farms being handed down at a low price from father to son or daughter, because they are simply not a profitable venture. In developed countries, farms suffer from a high equity ratio of 30–40% (Sparling and Laughland, 2007; Sparling and Uzea, 2012) and a revenue which can hardly justify such ratio. The high debt load results from a vicious circle of: farm owners compensating for their lack of revenue by borrowing against the increasing value of their property, and; a constantly increasing demand and price for land as farms expand to maintain their revenue against a poorer profit margin (Barrington, 2016). Such an increase in land value in Canada has attracted investors from abroad with further impact on price hike. In developing countries, farms are so small and of poor revenue, that only family members are interested in taking over to keep the property for the sake of the family. As a result, no new entrepreneurs besides the actual farming community have been interested in the industry. The lack of new entrepreneurs has impacted the capacity of the rural population around the world to innovate. The introduction of new practices is slowed down, including those related to climate change adaptation and sustainable resource management.

### 4.3 Impact on urban centres

Low profitability in rural sectors worldwide has led to a major migration of populations from rural areas to urban centres. Figure 3 illustrates the high correlation between gross domestic product (GDP) and urban population (UP) in 2005 for countries from all continents (Adhikari et al., 2009). As a country increases its GDP, its urban environment become more financially attractive and the economic gap widens between rural and urban areas. Some 20 years ago in many heavily populated Asian and South American countries, rural population accounted for almost 80% of the total population, whereas today, rural population has fallen to below 40%. If this trend continues to reach North American and European lows of 5%, Asian and South American countries will suffer major urban city crises (Figure 4).

Especially in Africa, Asia and South America, cities are facing an expansion crisis leading to issues such as transportation, energy supply, housing, drainage and garbage and wastewater collection and treatment. Cities have long been known to facilitate the provision of services, by concentrating users for example for power distribution and garbage pickup. But, mega cities produce the other extreme, resulting in more dependence on resources, and the need for higher capacity carriers for all aspects of life. A good example is the distance travelled by people working in mega cities, creating traffic jams wasting even more energy and generating atmospheric pollutants including greenhouse gases. For urban water supply, mega cities move a total of 504 million m³/day over a cumulative distance of 27,000 ± 3800 km covering 41% of the earth’s surface in watershed area (McDonald et al., 2014).

In terms of climate, mega cities result in a greater exposure to disastrous climatic events (United Nations, 2008). Besides higher atmospheric energies resulting from climate change, mega cities create strong localised atmospheric convective forces...
generating even more extreme climatic events (Ntelekos et al., 2007). Mega cities are heat islands at 1–2°C above surrounding regions and their tall buildings generate storms by increasing wind drag and upward convective velocities. As a city’s canopies is enlarged, convective climatic effects are enhanced. Today, mega cities are exposed to 30% more rainfall causing flash flooding and amplifying the climate change issue. Many cities find their drainage systems under designed, at a higher risk of flooding and water damage considering besides climate, large paved surfaces preventing rainfall infiltration and generating more runoff.

**Figure 3** Percentage urban population (UP) as a function of gross domestic product (GDP) for Africa, Asia, the Americas and Europe for 2005

![Graphs showing percentage urban population as a function of GDP for different regions](image)

*Source: Adhikari et al. (2009)*

Finally, many mega cities are located in coastal areas and their enlargement automatically augments the level of population exposed to tsunamis, the increasing occurrence of hurricanes and flooding as a result of higher sea levels.

Migration from rural to urban centres can be solved by creating a rural economy equivalent to that of cities. A more uniform population distribution around the world in both rural and urban areas would provide means of better adapting to climate change.
Figure 4  Trend of world and continental population from 2000 to 2050: (a) urban and (b) rural


4.4 Improving agricultural production with the same soil and water resources

The benefits of controlling global production to match consumption along with the introduction of adequate commodity prices at the farm would not only preserve agricultural resources to provide food safety for future generations but also relieve most of the poor population around the world (United Nations, 2015).

Africa offers the most obvious benefits. In Africa, a lack of financial means on farms to purchase mineral fertilisers and the use of high yielding varieties in the late 20th century has depleted soil minerals to extremely low levels. Africa has a tremendous potential for agricultural production, with large regions benefiting from high rainfalls. Higher soil fertility means: better crop yields; more residual organic matter to enrich the soil and increase its productivity; less land required to feed the population, and; less land exposed to desertification resulting from the overexploitation of fragile soils by the demands of an expanding population (United Nations, 2015). Land degradation affects more than 1 billion people, and results in the annual loss of 12 million ha. Also, better
fertilised crops make better use of irrigation water (Tani and Barrington, 2005) and can be more resistant to diseases and insects. In Africa alone, bringing soils back to a normal nutrient level would mean the same production on about 33% of the total land being presently used.

Globally, reducing food wastage from 35% to less than 10% and empowering rural communities will result in more than 40% less agricultural land being exploited and preserved to feed future populations. The land preserved beyond the 35% food wastage would result from improved productivity in continents such as Africa and South America were appropriate on-farm means use of fertiliser and pest management techniques would more than double crop yields, which increasing soil organic matter. Dropping food loses to an acceptable level of 5–10% worldwide, and reducing agricultural land usage by 40% would reduce annual fertiliser usage by 15–20 million tonnes for nitrogen and by 6–8 million tonnes for phosphorous, herbicide usage by 55–75 thousand tonnes, insecticide usage by 25–35 thousand tonnes and soil erosion by 2–5 billion tonnes annually (FAO, 2013b). The impact on world water resources would be tremendous, not because cropping practices pollutes but because all systems have normal losses.

In industrialised countries exporting agricultural produce, a lower production would be compensated by a higher price, thus providing the same on-farm revenue. For the consumer, doubling the farm share of the grocery price for many commodities would have little effect on food availability. In developed countries, the farm share represents 5–15% of the grocery price, meaning that doubling the at-the-farm price and eliminating wholesalers may have little impact on food cost. In developing countries, a higher price for food produce would be compensated by better revenues for the rural community, which could better afford not only its buy food but also to invest in post-harvest technologies for a safer long-term food supply.

4.5 Energy conservation

Production management systems would bring about energy conservation especially by promoting the use of local produce in season, as opposed to exposing local produce to international competition even when in season. In developed countries such as those of North America, farm produce travels over an average distance of 2000 km, often in refrigerated containers. For example, in 2008, oranges, bananas and apples consumed in grocery stores of the USA had travelled on the average 11,450, 3200 and 10,400 km, respectively (Bernatz, 2009). For the city of Edmonton Canada, organic produce sold in super markets had travelled 4200 km compared to 1500 km for conventional produce (Burt, 2010). The transportation of agricultural produce over such long distances, often in refrigerated containers, represent 15% of the total global energy consumption (Canning et al., 2010). Reducing food wastage from 35 to less than 10% would not have a major impact on energy usage in agriculture, as the primary agricultural sector only uses from 3% to 4% of the total global energy consumption.

4.6 Climate change adaptation

Climate change adaptation is a solution introduced to deal with earth warming trends. In terms of food security, this requires agricultural resources which are resilient in many cases to dryer and hotter conditions, or more intense rainfalls. Resilience for agricultural
soils means a high organic matter level capable of stocking moisture for the crop and retaining the applied fertilisers. It also means synchronised livestock and cropping system where crops are rotated from row crops to forages and where manure can be applied not just for its nutrients but also its organic matter. The only way to maintain a high organic matter level in field crops is to grow forages for cattle and recycle manure (Whalen and Barrington, 2008).

Climate change adaptation is therefore improved when considering the benefits of improving farm productivity by providing better sustainable means through a price at-the-farm established by a cost of production formula.

5 Conclusion

As opposed to modern world agricultural policies abolishing production management systems even in Canada, this paper promotes the introduction of such a system worldwide to reduce global food wastage from 35 to less than 10%, and institute food security measures through resource sustainability. At the same time, this system has the means of improving rural economy with wide spread socio-economic benefits for both the rural and urban populations: more uniform standard of living globally; improved education and higher entrepreneurship among the rural populations; higher capacity for climate change adaptation and less climatic disaster risks for the urban population, and; for urban centres, greater means of disposing of wastewaters and garbage, for a healthier environment.

Reducing food wastage and empowering rural communities will reduce agricultural land and water use by 40% and 20%, as soil productivity would be improved. In parallel, annual fertiliser and pesticide usage would drop by millions of tonnes, along with soil erosion, for a major improvement in world water resources, not because cropping practices pollutes but because all systems have normal losses.

Implementing a production management system worldwide for all food produce can be challenging although not unsurmountable. First of all, the system would require the implementation by a group of willing countries, which could be expanded over time as more would join. Because price competition is eliminated, local in season produce would be consumed first. Agricultural imports would apply to out of season produce or commodity in scarcity. The transition requires the provision of expert technical assistance and the adaptation and training of the farm producers to be able to wisely manage new revenues. Under such technical support, higher farm revenues would be invested partially towards improve environmental and sustainable practices. It would also mean developing a fair price accepted worldwide for more uniform global living standards, a result worth the implementation challenge.

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