BENIN

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Benin covers a land area of 114,763 square kilometers and occupies a long stretch of land perpendicular to the coast of the Gulf of Guinea in West Africa. It is bordered on the north by Burkina Faso and the Republic of Niger, on the east by the Federal Republic of Nigeria, and on the west by the Republic of Togo. With a 124-kilometer coastline, it stretches north to south some 672 kilometers and east to west 324 kilometers at its widest point. Most of the country experiences transitional tropical conditions, with less rainfall than in other areas at the same latitude—a climate known as the Benin variant, marked by a dry season from November to early April and a rainy season from mid-April to October.

Climate change, as a worldwide concern, implies generally warmer temperatures as well as changes in precipitation patterns, with more extreme weather events and shifting seasons. Agriculture is especially vulnerable, and climate change will thus disproportionately affect the poor, who depend on agriculture for their livelihoods and who have a lower capacity to adapt. The population of Benin is projected to at least double (to 18 million) or possibly more than triple (to 25 million) by 2050, with increasingly densely populated urban areas. The share of agriculture in gross domestic product (GDP) is expected to stagnate or increase, indicating that nonagricultural sectors of the economy will be stagnant at best. This chapter assesses the vulnerability of the agricultural sector of Benin to climate change to provide the basis for designing informed policies to meet those challenges. The study focuses on Benin’s main foodcrops: yams, cassava, maize, and other roots and tubers.

The climate models show different outcomes for precipitation levels in Benin in 2050. CNRM-CM3 and ECHAM 5 show increased precipitation, while the two other models (CSIRO Mark 3 and MIROC 3.2) show areas of
precipitation decrease, mainly in the south. All four general circulation models (GCMs) show an increase in the normal annual maximum temperature for the whole country, ranging from slight (1°–1.5°C for MIROC 3.2) to substantial (2.5°–3.0°C for ECHAM 5). These changes in climate affect crop production simulations in varying ways. For instance, for a given GCM the modeled spatial changes in maize production generally track changes in precipitation.

The purpose of this chapter is to help policymakers and researchers better understand and anticipate the likely impacts of climate change on agriculture, as well as on vulnerable households in Benin. The study on which it is based reviewed current data on agriculture and economic development and modeled the effects of anticipated changes in climate between now and 2050 using crop models to assess the impact of climate changes on agricultural production. The study further modeled future supply and demand for food to show trends in food prices and trade. Policy options are presented for reducing the impacts of climate change on agriculture in Benin.

Review of the Current Situation

Population
Figure 3.1 shows trends in the size of the total population and the rural population (left axis), along with the share of the urban population (right axis). According to the third census of Benin (Benin, INSAE 2003), the country’s total population was 6.8 million in 2003. From about 27 percent in 1980, the share of urban population rose to 40 percent in 2008 (see Figure 3.1). The rural sector, though declining in percentage of population, will continue to play an important role in providing the agricultural workforce as well as in creating potential demand for goods and services. Benin’s population growth rate increased from 1.9 during 1960–69 to 3.3 during 1990–99 (Table 3.1).

Figure 3.2 shows the geographic distribution of Benin’s population as of 2000. The population is unevenly distributed between the southern and northern regions and between rural and urban areas. The share of the population per region decreases going from the south (51.5 percent) to the north (31.7 percent). Most of the population is concentrated in the southern region, between latitudes 6.35°N and 7.18°N.

1 CNRM-CM3 is National Meteorological Research Center–Climate Model 3. ECHAM 5 is a fifth-generation climate model developed at the Max Planck Institute for Meteorology in Hamburg. CSIRO Mark 3 is a climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation. MIROC 3.2 is the Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.
FIGURE 3.1 Population trends in Benin: Total population, rural population, and percent urban, 1960–2008

Source: World Development Indicators (World Bank 2009).

TABLE 3.1 Population growth rates in Benin, 1960–2008 (percent)

<table>
<thead>
<tr>
<th>Decade</th>
<th>Total growth rate</th>
<th>Rural growth rate</th>
<th>Urban growth rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960–69</td>
<td>1.9</td>
<td>1.1</td>
<td>7.8</td>
</tr>
<tr>
<td>1970–79</td>
<td>2.5</td>
<td>1.2</td>
<td>7.5</td>
</tr>
<tr>
<td>1980–89</td>
<td>2.9</td>
<td>1.9</td>
<td>5.3</td>
</tr>
<tr>
<td>1990–99</td>
<td>3.3</td>
<td>2.7</td>
<td>4.4</td>
</tr>
<tr>
<td>2000–2008</td>
<td>3.3</td>
<td>2.7</td>
<td>4.2</td>
</tr>
</tbody>
</table>

Source: Authors’ calculations based on World Development Indicators (World Bank 2009).

Income

The level of income available to an individual is a widely used indicator of resilience to stresses. Figure 3.3 shows trends in Benin’s GDP per capita as well as the proportion of GDP from agriculture (agriculture GDP). The share of income earned in agriculture shows the importance of the agricultural sector for the economy. In general, as development increases, the importance of agriculture in GDP tends to decline.
The share of GDP from agriculture steadily decreased from the mid-1960s to the mid-1970s; agriculture GDP has since fluctuated between 30 and 38 percent. Per capita GDP fluctuated between 1960 and 1990, but with a slight upward trend. Since 1990 there has been a steadier increase in per capita GDP, which rose to $360 in 2008, an increase that can be attributed to the liberalization of the country’s economy.

Vulnerability to Climate Change

Vulnerability has many dimensions. This chapter focuses on income as a determinant of vulnerability or resilience, addressing both level and source of income. Table 3.2 provides some data on additional indicators of the vulnerability and resilience of the population to economic shocks: education level, literacy, and concentration of labor in poorer or less dynamic sectors of the economy.

Benin’s primary school enrollment, at 95.9 percent, is among the highest in the region. However, the secondary school enrollment rate is still low (32.5 percent), as in most other countries in the region. The adult literacy rate is also low, at 40.5 percent. The under-five malnutrition rate is high (21.5 percent in 2001), correlated with high adult illiteracy and low per capita GDP.

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2 All dollar figures are constant 2000 US dollars.
Although living conditions in Benin remain underdeveloped, there has been considerable improvement since the 1960s, as shown in Figure 3.4. The under-five mortality rate has decreased by half, from more than 250 per 1,000 in the late 1960s to about 125 per 1,000 in 2008; life expectancy at birth increased by half between 1964 and 2008, from 40 to 60 years. These positive developments are the result of multiple livelihood-improvement policy actions, including a food security program as well as health programs to
address malaria, AIDS, poliomyelitis, and child healthcare issues. The recently implemented free-of-charge Caesarean delivery program is expected to further improve child delivery conditions.

The high percentage of the population living on less than US$2 (US dollars) per day illustrates the general poverty level of the country (Figure 3.5). Poverty is acute in the northernmost part of Benin as well as in parts of the coastal area. Note that the Atlantique-Littoral region and other southern regions, with a lower percentage of people living on less than US$2, host a majority of the population.

**Review of Land Use and Agriculture**

**Land Use Overview**

Although the southern part of Benin is situated within the evergreen forest belt of West Africa, the coastal areas of the country (and neighboring Togo), with northern savannalike vegetation, form part of the notably dry Dahomey Gap (Salzmann and Hoelzmann 2005). In general, Benin is dominated by...
shrub cover (closed-open, deciduous), followed by broadleaved tree cover and mosaic systems (cropland and shrub) (Figure 3.6). The country has several protected areas concentrated in the central and the northern parts of the country, as well as two main cross-border national parks (Pendjari and W) in the far northwest (see Figure 3.7).\(^3\)

Figure 3.8 shows the stylized travel times to urban areas of various sizes. These four maps may be helpful for the reader to approximate the transport costs of agricultural inputs and consumables to farms and of farm output to markets. The larger cities of greater population density and size (500,000 or more) are concentrated in the south: Cotonou, Godomey, Calavi, and Porto-Novo (see Figure 3.8). It is a challenge to transport agricultural produce from the north to the urban centers in the south and imported goods in the reverse direction. The situation is somewhat better for the medium-sized and small cities distributed across the country (populations between 25,000 and 10,000); however, the market is smaller in these regions.

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\(^3\) The International Union for Conservation of Nature (IUCN) classifies protected areas according to their management objectives. The protected area categories are outlined at www.iucn.org/about/work/programmes/pa/pa_products/wcpa_categories/.
FIGURE 3.6  Land cover and land use in Benin, 2000

Source: GLC2000 (Bartholome and Belward 2005).

FIGURE 3.7  Protected areas in Benin, 2009

Sources: Protected areas are from the World Database on Protected Areas (UNEP and IUCN 2009). Water bodies are from the World Wildlife Fund’s Global Lakes and Wetlands Database (Lehner and Döll 2004).
FIGURE 3.8  Travel time to urban areas of various sizes in Benin, circa 2000

Source: Authors’ calculations.
Agriculture Overview

Maize, yams, and cassava are the three major food crops cultivated in Benin (Table 3.3). Seed cotton is the major cash crop grown in the country, followed by cashew nuts. Yams and cassava are the major staple food crops, followed by maize (Table 3.4).

**TABLE 3.3** Harvest area of leading agricultural commodities in Benin, 2006–08 (thousands of hectares)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Crop</th>
<th>Percent of total</th>
<th>(Thousands of hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>100.0</td>
<td>2,222</td>
</tr>
<tr>
<td>1</td>
<td>Maize</td>
<td>30.6</td>
<td>679</td>
</tr>
<tr>
<td>2</td>
<td>Seed cotton</td>
<td>10.1</td>
<td>225</td>
</tr>
<tr>
<td>3</td>
<td>Cashew nuts</td>
<td>9.5</td>
<td>212</td>
</tr>
<tr>
<td>4</td>
<td>Yams</td>
<td>8.3</td>
<td>185</td>
</tr>
<tr>
<td>5</td>
<td>Cassava</td>
<td>7.9</td>
<td>175</td>
</tr>
<tr>
<td>6</td>
<td>Sorghum</td>
<td>6.7</td>
<td>149</td>
</tr>
<tr>
<td>7</td>
<td>Beans</td>
<td>6.5</td>
<td>145</td>
</tr>
<tr>
<td>8</td>
<td>Groundnuts</td>
<td>5.2</td>
<td>116</td>
</tr>
<tr>
<td>9</td>
<td>Millet</td>
<td>1.9</td>
<td>42</td>
</tr>
<tr>
<td>10</td>
<td>Other pulses</td>
<td>1.4</td>
<td>31</td>
</tr>
</tbody>
</table>

Source: FAOSTAT (FAO 2010).
Note: All values are based on the three-year average for 2006–08.

**TABLE 3.4** Consumption of leading food commodities in Benin, 2003–05 (thousands of tons)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Crop</th>
<th>Percent of total</th>
<th>Food consumption (thousands of hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>100.0</td>
<td>4,176</td>
</tr>
<tr>
<td>1</td>
<td>Yams</td>
<td>25.1</td>
<td>1,048</td>
</tr>
<tr>
<td>2</td>
<td>Cassava</td>
<td>25.0</td>
<td>1,044</td>
</tr>
<tr>
<td>3</td>
<td>Maize</td>
<td>11.4</td>
<td>475</td>
</tr>
<tr>
<td>4</td>
<td>Rice</td>
<td>4.8</td>
<td>200</td>
</tr>
<tr>
<td>5</td>
<td>Other vegetables</td>
<td>4.7</td>
<td>197</td>
</tr>
<tr>
<td>6</td>
<td>Tomatoes</td>
<td>3.6</td>
<td>152</td>
</tr>
<tr>
<td>7</td>
<td>Sorghum</td>
<td>3.1</td>
<td>131</td>
</tr>
<tr>
<td>8</td>
<td>Other fruits</td>
<td>2.6</td>
<td>108</td>
</tr>
<tr>
<td>9</td>
<td>Pineapples</td>
<td>2.4</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>Chicken</td>
<td>1.7</td>
<td>72</td>
</tr>
</tbody>
</table>

Source: FAOSTAT (FAO 2010).
Note: All values are based on the three-year average for 2003–05.
Figures 3.9–3.11 show the estimated yield and growing areas for key crops in Benin. Maize is more widely cultivated in the southern regions than in the central zones (see Figure 3.9). The production profiles for yams, sweet potatoes, and cassava are similar, although yam and sweet potato production is limited to the southeast and northwestern areas (see Figure 3.10), while cassava is quite rare in the north of the country (see Figure 3.11). Maize yields range from 1 to 2 metric tons per hectare, while the yields of fresh roots and tubers range from 7 to 10 metric tons per hectare across the country.⁴

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⁴ All tons are metric tons.
Economic and Demographic Scenarios

Population
The population of Benin, projected by the government to be 8.5 million for 2010 (Benin, INSAE 2003) and projected by the United Nations to be 10.0 million (UNPOP 2009), is expected to at least double and possibly grow to more than two and a half times that size by 2050: the low variant is approximately 21 million, while the high variant is almost 27 million (Figure 3.12). These projections correspond to average densities of 186 and 237 people per square kilometers for the low and high variants, respectively.
**Income**

Figure 3.13 presents three scenarios for GDP per capita, derived by combining three GDP projections with the three population projections of Figure 3.12 (based on United Nations population data). The optimistic scenario combines high GDP with low population, the baseline scenario combines the medium GDP projection with the medium population projection, and the pessimistic scenario combines the low GDP projection with the high population projection. The agricultural modeling in the next section uses these scenarios.

Benin’s GDP per capita has been steadily increasing since 1990 and is presently around US$360. According to both the optimistic and the baseline scenarios, GDP is projected to increase. According to the pessimistic scenario, however, per capita GDP will actually decline.
FIGURE 3.12  Population projections for Benin, 2010–50

![Graph showing population projections for Benin, 2010–50. The graph illustrates three variants: High variant, Medium variant, and Low variant, with projections for years 2010 to 2050.]

Source: UNPOP (2009).

FIGURE 3.13  Gross domestic product (GDP) per capita in Benin, future scenarios, 2010–50

![Graph showing gross domestic product (GDP) per capita in Benin, future scenarios, 2010–50. The graph illustrates three scenarios: Pessimistic, Baseline, and Optimistic, with projections for years 2010 to 2050.]

Biophysical Scenarios

Climate Scenarios

Precipitation
Figure 3.14 shows precipitation changes predicted for Benin in the four downscaled climate models we use in this chapter for the A1B scenario.⁵ CNRM-CM3 and ECHAM 5 show increased rainfall for some parts of the country and no significant decline for any part of the country. However, the two other models show a precipitation decrease in either most of the country (CSIRO) or just the southern region (MIROC). Although the MIROC model shows less rainfall in the most agriculturally productive part of the country, it also shows increased rainfall in sections that currently experience low rainfall. If this model proves to be most accurate, that should imply that some of the agricultural production for the country will shift northward. On the other hand, livestock production adapted to the relatively drier northern region could be affected by the possible increase in the incidence of pests and diseases associated with wet conditions. Adapting to such changes would require appropriate crop varieties and animal breeds as well as matching management practices, including efficient management of water in drought conditions and control of floods.

Temperature
Figure 3.15 shows how the daily high temperatures would change during the warmest month in the A1B scenario. The models show an increase in temperature ranging from 1°–1.5°C (based on MIROC 3.2, medium resolution) to 2.0°–2.5°C (based on CNRM-CM3). CSIRO Mark 3 shows a rise of 1.5°–2.0°C in most parts of the country except for the coastal areas, which have a lower temperature, while ECHAM 5 shows a rise of 2.0°–2.5°C for the northernmost part of the country and 1.5°–2.0°C for the rest of the country. Such increases in temperature could pose a serious threat to the productivity as well as the survival of certain crop species and to biodiversity in general, on which farmers in the country rely heavily. Consequently, adaptation to increases in temperature would require the development of crop varieties that could tolerate such conditions.

⁵ The A1B scenario is a greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources.
FIGURE 3.14 Changes in mean annual precipitation in Benin, 2000–2050, A1B scenario (millimeters)

Source: Authors’ calculations based on Jones, Thornton, and Heinke (2009).
Notes: A1B = greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources; CNRM-CM3 = National Meteorological Research Center–Climate Model 3; CSIRO = climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation; ECHAM 5 = fifth-generation climate model developed at the Max Planck Institute for Meteorology (Hamburg); GCM = general circulation model; MIROC = Model for Interdisciplinary Research on Climate, developed by the University of Tokyo Center for Climate System Research.
FIGURE 3.15  Change in monthly mean maximum daily temperature in Benin for the warmest month, 2000–2050, A1B scenario (°C)

Source: Authors’ calculations based on Jones, Thornton, and Heinke (2009).
Notes: A1B = greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources; CNRM-CM3 = National Meteorological Research Center–Climate Model 3; CSIRO = climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation; ECHAM 5 = fifth-generation climate model developed at the Max Planck Institute for Meteorology (Hamburg); GCM = general circulation model; MIROC = Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.
Crop Physiological Responses to Climate Change
The yield results from the Decision Support Software for Agrotechnology Transfer (DSSAT) using 2050 climate from each GCM were compared to the yields simulated with unchanged (2000) climate.

The output for rainfed maize yields is mapped in Figure 3.16. DSSAT outputs for all four GCMs show a slight increase in maize yield (5–25 percent of baseline) for the far northern part of the country. For the central and the southern parts of the country (covering the most productive zone of maize), the models show significant maize yield reductions (5–25 percent of baseline), with CSIRO Mark 3 showing greater losses.

Agricultural Vulnerability Scenarios (Crop-Specific)
Maize
Figure 3.17 shows the combined effects of climate change and economic developments on maize from now to 2050. There is little or no difference among the scenarios for maize area, production, and yield. All the scenarios show the harvested area for maize increasing slightly in the near future and stagnating after 2020 (at around 800,000 hectares). The maize yield is shown to significantly improve, doubling to 2 tons per hectare, effecting an increase in overall production. It should be noted that there are currently maize varieties that have a yield potential higher than 2 tons per hectare; achieving these yields will depend on improved management practices. Projected net export levels differ, however. In the baseline and optimistic scenarios, maize exports rise steadily; the pessimistic scenario shows a modest increase in exports followed by a decrease to just above the current level—despite the modeled increase in the world price of maize. This trend could be explained by the increase in population, and hence increased domestic consumption, in the pessimistic scenario.

Yams and sweet potatoes
For yams and sweet potatoes the three scenarios produce almost identical results for all areas of Benin. According to all the scenarios, yam and sweet potato production will almost double, increasing to close to 4 million tons as a consequence of significant yield improvement (doubling from 11 to 20 tons per hectare)—even though the harvested area is shown to slightly decrease after 2020 (Figure 3.18). Net exports are shown to stagnate until 2025 and then decrease, with the country importing yams and sweet potatoes by 2050. The country is likely to face a difficult situation, because the world price will significantly increase according to all three scenarios.
FIGURE 3.16 Yield change under climate change: Rainfed maize in Benin, 2000–2050, A1B scenario

2000 old area lost
Yield loss > 25% of 2000
Yield loss 5–25%
Yield change within 5%
Yield gain 5–25%
Yield gain > 25%
2050 new area gained

Source: Authors’ estimates.

Notes: A1B = greenhouse gas emissions scenario that assumes fast economic growth, a population that peaks midcentury, and the development of new and efficient technologies, along with a balanced use of energy sources; CNRM-CM3 = National Meteorological Research Center–Climate Model 3; CSIRO = climate model developed at the Australia Commonwealth Scientific and Industrial Research Organisation; ECHAM 5 = fifth-generation climate model developed at the Max Planck Institute for Meteorology (Hamburg); GCM = general circulation model; MIROC = Model for Interdisciplinary Research on Climate, developed at the University of Tokyo Center for Climate System Research.
FIGURE 3.17  Impact of changes in GDP and population on maize in Benin, 2010–50

Production

Yield

Area

Net exports

Prices

Source: Based on analysis conducted for Nelson et al. (2010).

Notes: The box and whiskers plot for each socioeconomic scenario shows the range of effects from the four future climate scenarios. GDP = gross domestic product; US$ = US dollars.
FIGURE 3.18  Impact of changes in GDP and population on yams and sweet potatoes in Benin, 2010–50

Production

Yield

Area

Net exports

Prices

Source: Based on analysis conducted for Nelson et al. (2010).
Notes: The box and whiskers plot for each socioeconomic scenario shows the range of effects from the four future climate scenarios. GDP = gross domestic product; US$ = US dollars.
Cassava and Other Roots and Tubers
Cassava production and yield are shown to improve until 2030 and then stagnate, at between 3 and 4 million metric tons and at just over 15 tons per hectare, respectively (Figure 3.19). The harvested area does not change much over 2010–50 in any of the scenarios. Net exports of cassava and other roots and tubers will decrease significantly, from an initial zero level. The resulting growth in imports will be at a steady or modestly increasing world price, with detrimental consequences for the economy.

Human Vulnerability Scenarios
In Figure 3.20 we see that the scenarios have dramatically different outcomes for the number of malnourished children under age five. In the baseline scenario, the number is shown to slightly increase; in the pessimistic scenario, the number almost doubles by 2050; and in the optimistic scenario, the number of malnourished children under age five in Benin would continue to increase slightly until 2030 and then decline to about 400,000.

Similarly, the availability of kilocalories per capita is shown to decrease slightly in the baseline scenario and decline significantly in the pessimistic scenario. In the optimistic scenario, a significant increase is foreseen after 2030 (Figure 3.21). These results of IMPACT clearly indicate that there is a vital need for Benin to develop and implement a food security policy with enabling conditions for resource-poor farmers, including safety nets.

Conclusions and Policy Recommendations
The total population of Benin is increasing rapidly, at a rate of 3.3 percent. There will therefore be a growing number of mouths to feed against the background of the adverse effects of climate on food production. In some scenarios, the most productive zone for staple crops could experience reduced precipitation as well as an average increase of 2°C in temperature, with substantial negative effects on staple yields (e.g., a decline of 5–25 percent for maize).

Yams, cassava, and maize are currently the main food products consumed in the country. Net exports of maize are shown to increase, either significantly (in the optimistic and baseline scenarios) or slightly (in the pessimistic scenario). For tubers and root crops (yams, sweet potatoes, cassava, and others), imports will grow in all scenarios. Because the world price of all these commodities will increase, exports of maize will benefit the country, while imports of tubers and root crops will negatively affect the balance of trade. Investment
FIGURE 3.19  Impact of changes in GDP and population on cassava in Benin, 2010–50

Production

Yield

Area

Net exports

Prices

Source: Based on analysis conducted for Nelson et al. (2010).
Notes: The box and whiskers plot for each socioeconomic scenario shows the range of effects from the four future climate scenarios. GDP = gross domestic product; US$ = US dollars.
in agricultural productivity for these crops could help raise farmers’ incomes and reduce imports and maximize exports.

Our policy recommendations for adapting to the agricultural effects of climate change are as follows:

- Take appropriate steps to monitor climate and provide relevant information for early warning of likely climate change and adverse consequences.
- Support agricultural research efforts aimed at developing and identifying crop varieties of the major staples that could be more adaptive to climate change.
- Promote the development and adoption of more efficient water-use techniques.
- Support the capacity building of farmers with regard to access to and improved use of climate information.
- Establish crop marketing networks and access to inputs that will ensure improved marketing to stimulate agricultural production.
Take adequate steps to slow population growth and thus avoid imposing tremendous pressure on the natural resource base for food production. These approaches are widely recognized as essential to support agriculture.

References


