

## Lesson Plan: Photosynthetic Pathways and Physiological Responses to Climate Change

As an **undergraduate Biological Sciences** teacher, you can use this set of computer-based tools to teach about differences in **photosynthesis** in different types of plants (**C3, C4 and CAM**) and how they are affected by climate change: which is more resilient or less resilient. You can discuss all these basic concepts in plant physiology using the case study: Uganda's massive expansion of Bamboo, a C3 plant, to address the issue of heavy deforestation, under changing climatic conditions.

This lesson plan includes resources that teach about the C3, C4 photosynthetic pathways in plants and describes the differences in their physiological responses to changing environmental conditions like rising atmospheric concentrations of CO<sub>2</sub> and temperatures. You can also use these resources to teach photorespiration, nutrient and water uptake, stomatal conductance, carbon -fixation and, more importantly, homeostasis for **photosynthetic efficiency** under these varying conditions. Use this lesson plan to explain how this understanding can be applied to devise climate adaptation strategies by using the example of large-scale Bamboo plantation in Uganda.

Thus, the use of this lesson plan allows you to integrate the teaching of a climate science topic with a core topic in **Biological Sciences (specifically Plant Physiology)**.

Use this lesson plan to help your students find answers to:

1. What are C3, C4, and CAM plants? Describe the differences in their photosynthetic pathways.
2. Describe what factors have the most impact on the photosynthetic efficiencies of C3, C4 and CAM plants.
3. How global warming and higher CO<sub>2</sub> concentrations may affect the growth and development of C3, C4 and CAM plants?
4. Explain physiological limitations in C3, C4 and CAM plants to adapt to climate change.
5. How is a C3 plant Bamboo, suited to restore the fractured forest ecosystems of Uganda?

## About the Lesson Plan

**Grade Level:** Undergraduate

**Discipline:** Biological Sciences

**Topic(s) in Discipline:** Plant Physiology, Photosynthetic Pathways, C3, C4, and CAM Plants, Photorespiration, Stomatal Conductance, Photosynthetic Efficiency, Temperature Adaptation, Temperature Acclimation, Homoeostasis

**Climate Topic:** Climate and the Biosphere, Climate Mitigation and Adaptation

**Location:** Global, Uganda

**Access:** Online, Offline

**Language(s):** English

**Approximate Time Required:** 80 min

# 1 Contents

## 1. Video micro-lecture (~12 min)

A micro-lecture that introduces the topic of photosynthesis and describe the differences in C3, C4 and CAM photosynthetic pathways in plants.

This can be accessed at:

<https://www.bozemanscience.com/photosynthesis>

## 2. Video micro-lecture (7.5 min)

A video micro-lecture that introduces the C3, C4 photosynthetic pathways and explains how plants have evolved to respond differently to changing climatic conditions.

This can be accessed at:

<https://www.youtube.com/watch?v=5ti09qMaLZU>

## 3. Readings (40 min)

Two readings that describe the photosynthetic responses of plants to factors of climate change:

- A reading to discuss the difference in the responses of C3 and C4 plants to rising levels of atmospheric CO<sub>2</sub>.

<https://www.nature.com/scitable/knowledge/library/effects-of-rising-atmospheric-concentrations-of-carbon-13254108>

- A reading to describe the differences in temperature adaptation and acclimation for the C3, C4 photosynthetic pathways.

<http://publish.uwo.ca/~dway4/files/Yamori%20et%20al.%202013.pdf>

#### 4. Readings (20 min)

Two readings to discuss the extensive planting of a C3 plant Bamboo, in Uganda:

- A case study of Bamboo For Good (B4G) initiative that has program partnerships in Uganda and other East African Countries for growing Bamboo to address 'critical social, economic, environmental, and wildlife habitat needs'.

<https://pacificbamboo.org/bamboo-for-good/>

- A tabular representation of the attributes of planting Bamboo as a climate adaptation strategy against human-induced large-scale deforestation.

<http://www.fao.org/tempref/docrep/fao/012/k6887e/k6887e00.pdf> page 28, Table 3.

#### 5. Suggested questions/assignments for learning evaluation

- What are C3, C4, and CAM plants? Describe the differences in their photosynthetic pathways.
- Describe what factors have the most impact on the photosynthetic efficiencies of C3, C4 and CAM plants.
- How global warming and higher CO<sub>2</sub> concentrations may affect the growth and development of C3, C4 and CAM plants?
- Explain physiological limitations in C3, C4 and CAM plants to adapt to climate change.
- How is a C3 plant Bamboo, suited to restore the fractured forest ecosystems of Uganda?

## 2 Step-by-step User Guide

Here is a step-by-step guide to using this lesson plan in the classroom/laboratory. We have suggested these steps as a possible plan of action. You may customize the lesson plan according to your preferences and requirements.

### 1. Topic introduction and discussion

Introduce the topic by playing the video micro-lecture, "[Photosynthesis](#)" from bozemanscience. This video explains the process of photosynthesis, chloroplasts and photoreceptors, the light reaction and the Calvin cycle, and gives an overview of photosynthetic pathways in C3, C4, and CAM plants. Use the video to explain how these pathways are affected by stomatal conductance, which in turn affects nutrient and water uptake by the plants. Further, explain the influence of photorespiration on photosynthetic efficiencies and thereby, carbon fixation in C3, C4 plants- use the resource, 'C3, C4, and CAM plants. How the C4 and CAM pathways help minimize photorespiration.' by Khan Academy, from the additional resources section, to explain this in detail.

The video micro-lecture can be accessed at:

<https://www.bozemanscience.com/photosynthesis>.

### 2. Extend discussion to explain how the C4/CAM plants have evolved in response to climate change

Play the video micro-lecture, '[Plant Response to Climate Change](#)' by Prof. Raghu Murtugudde (content developed at Science Media Centre, IISER Pune), to explain that C3 and C4 type plants evolved differently as a response to changes in temperature and CO<sub>2</sub> levels. This micro-lecture explains the possible influence of CO<sub>2</sub> levels and climate change on the growth of plants and consequently on vegetation and crop productivity.

The video micro-lecture is accessible at

<https://www.youtube.com/watch?v=5ti09qMaLZU>.

### 3. Further the understanding of the effect of climate change on the photosynthetic efficiencies of plants

Provide your students with printouts of the following readings to discuss the influence of climate change related factors- increased atmospheric CO<sub>2</sub> and rising global temperatures-on the photosynthetic efficiencies of C3 and C4 plants.

Use the reading "[Effects of Rising Atmospheric Concentrations of Carbon Dioxide on Plants](#)" from Nature Education to discuss the effects of elevated CO<sub>2</sub> levels on the photosynthetic efficiency of field-grown plants. Use the text to explain that plant physiology and biochemical compositions change in response to high CO<sub>2</sub> availability. Secondary effects like changes in stomatal conductance affect efficiency of carbon fixation and water uptake in plants. Thus, differences in the responses of C3 and C4 plants under these conditions are noted. Discuss the results showing a higher rate of photosynthesis for C3 plants with increased CO<sub>2</sub> atmospheric concentrations compared to C4 plants.

This can be accessed at:

<https://www.nature.com/scitable/knowledge/library/effects-of-rising-atmospheric-concentrations-of-carbon-13254108>

Use the reading, '[Temperature response of photosynthesis in C3, C4, and CAM plants: temperature acclimation and temperature adaptation](#)', from Springer Science+Business Media, to explain how the type of photosynthetic pathway determines the ability of a plant to respond to climate related temperature changes. Use this reading to discuss plant phenotypic plasticity, temperature acclimation and temperature adaptation in terms of photosynthetic efficiencies of C3 and C4 plants. Discuss this in conjunction with the perceived improved photosynthetic efficiency of C3 plants at higher temperatures compared to C4 plants.

This can be accessed at:

<http://publish.uwo.ca/~dway4/files/Yamori%20et%20al.%202013.pdf>

### 4. Discuss the case study of Bamboo Plantation in Uganda

Two readings to discuss the extensive planting of a C3 plant Bamboo, in Uganda:

Use the resource, '[B4G- Bamboo For Good](#)' by Pacific Bamboo Resources, to discuss the case study of a collaborative effort of a number of public and private institutions to 'mobilize bamboo resources for good' in East Africa and specifically in Uganda. Navigate to various tabs on the website to learn more about the partnership programs in Uganda that work towards 'social empowerment, economic vitality, and environmental health' through its different projects.

This can be accessed at:

<https://pacificbamboo.org/bamboo-for-good/>

Use this table- Table 3. Bamboo attributes for climate change, page 28- from '[The poor man's carbon sink: Bamboo in Climate Change and Poverty Alleviation](#)' by the Food and Agricultural Organization (FAO), to discuss the attributes of Bamboo as the plant chosen to provide a fast growing and sustainable green cover to restore the human-induced fragmented forest ecosystems of Uganda. In the context of this lesson plan, discuss the advantages and disadvantages of using Bamboo as a climate adaptation strategy against deforestation in Uganda. Elaborate on the possibility of improved photosynthetic efficiency of this species under increased temperature and atmospheric CO<sub>2</sub> conditions. Discuss how this contrasts with its sensitivity towards water stress and drought like conditions, the other aspects of climate related factors that impact photosynthetic efficiencies of C<sub>3</sub> plants.

This can be accessed at:

<http://www.fao.org/tempref/docrep/fao/012/k6887e/k6887e00.pdf>

Use the resources (one video and one reading) in the additional resources section of this lesson plan to discuss the usage of Bamboo to restore vegetation in large areas of Uganda that are denuded of natural forest cover due to deforestation by anthropogenic activities.

## 5. Questions/Assignments

Use the tools and the concepts learned so far to discuss and determine answers to the following questions:

- What are C<sub>3</sub>, C<sub>4</sub>, and CAM plants? Describe the differences in their photosynthetic pathways.
- Describe what factors have the most impact on the photosynthetic efficiencies of C<sub>3</sub>, C<sub>4</sub> and CAM plants.
- How global warming and higher CO<sub>2</sub> concentrations may affect the growth and development of C<sub>3</sub>, C<sub>4</sub> and CAM plants?
- Explain physiological limitations in C<sub>3</sub>, C<sub>4</sub> and CAM plants to adapt to climate change.
- How is a C<sub>3</sub> plant Bamboo, suited to restore the fractured forest ecosystems of Uganda?

## 3 Learning Outcomes

The tools in this lesson plan will enable students to:

- discuss the differences in C3, C4 and CAM plants
- explain the evolution of C4, CAM plants in response to climate change
- explain the impact of environmental variations on photosynthetic efficiencies in C3, C4 plants
- describe how climate related factors affect photosynthesis in plants
- discuss the role of Bamboo in restoring the denuded forest vegetation in Uganda

## 4 Additional Resources

If you or your students would like to explore the topic further, these additional resources will be useful.

### 1. Reading

A reading, 'C3, C4, and CAM plants: How the C4 and CAM pathways help minimize photorespiration' by Khan Academy, to explain photorespiration in plants and to describe how this affects the photosynthetic efficiencies of C3, C4 and CAM plants.

This can be accessed at:

<https://www.khanacademy.org/science/biology/photosynthesis-in-plants/photorespiration--c3-c4-cam-plants/a/c3-c4-and-cam-plants-agriculture>



## 2. Resources for Bamboo Planting in Uganda

- A video, 'Ugandan environmentalists plant over 11,000 bamboo seedlings' by CGTV Africa, to show Uganda's efforts to combat deforestation in a changing climate using Bamboo: <https://www.youtube.com/watch?v=18h4mjRCUal>
- A reading, 'Climate Change and Biodiversity in Uganda' (Section 4.3, page 17) by U.S. Agency for International Development (USAID), that includes bamboo planting in Uganda as a climate resilient ecosystem: [https://www.climatelinks.org/sites/default/files/asset/document/Uganda%2520CC%2520and%2520Biodiversity%2520Overview\\_CLEAR\\_ED\\_0.pdf](https://www.climatelinks.org/sites/default/files/asset/document/Uganda%2520CC%2520and%2520Biodiversity%2520Overview_CLEAR_ED_0.pdf)

## 5 Credits/Copyrights

All the teaching tools in our collated list are owned by the corresponding creators/authors/organizations as listed on their websites. Please view the individual copyright and

ownership details for each tool by following the individual links provided.

We have selected and analyzed the tools that align with the overall objective of our project and have provided the corresponding links. We do not claim ownership of or responsibility/liability for any of the listed tools.

### 1. Video micro-lecture; "Photosynthesis"

Narrated and developed by [Paul Andersen](#).

### 2. Video micro-lecture; "Plant Response to Climate Change"

Narrated by [Prof Raghu Murtugudde](#), content developed for the TROP ICSU project, developed at the [Science Media Centre, IISER Pune](#).

### 3. Reading, “Effects of Rising Atmospheric Concentrations of Carbon Dioxide on Plants”

By: Daniel R. Taub (Biology Department, Southwestern University) © 2010 Nature Education

Citation: Taub, D. (2010) Effects of Rising Atmospheric Concentrations of Carbon Dioxide on Plants. Nature Education Knowledge 3(10):21

### 4. Reading, “Temperature response of photosynthesis in C3, C4, and CAM plants: temperature acclimation and temperature adaptation”

Citation: Yamori, W., Hikosaka, K. & Way, D.A. Photosynth Res (2014) 119: 101. <https://doi.org/10.1007/s11120-013-9874-6>

### 5. Reading, “B4G: Bamboo For Good”

By [Pacific Bamboo Resources](#).

### 6. Reading, “The poor man’s carbon sink: Bamboo in Climate Change and Poverty Alleviation”

By the [Food and Agricultural Organization \(FAO\)](#)

### 7. Additional Resources

[Khan Academy](#)

[CGTV Africa](#)

[U. S. Agency for International Development \(USAID\)](#)