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Nature & The Neomnivore

The Cellular Agriculture Environmental Impact Compendium

Proposed Biennial/Annual Submission – Version 1

August 4th, 2017

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Abstract

Animal agriculture, at its current scale, requires an exceptional degree of ecological resources and is among the most overlooked causes of environmental detriment.

This report seeks to segment the basis for animal agriculture's contribution to greenhouse gas emissions, fresh water consumption, and arable land use, among other tangential environmental consequences of animal husbandry. Upon establishment of the salience of these issues, this report will guide examination of an alternative method of animal product acquisition, cellular agriculture. A primary purpose of this report is to concisely illustrate the impact of animal agriculture environmentally, and the consequential mitigation potential of cellular agriculture. Thus, the novel effort of examining the global, environmental prospective impact of cellular agriculture's societal adoption is the principal aim of this compendium, and hence, reasoning for environmental neomnivorism will be established.

Suggested Environmental Categories for Future Reports



Ocean
dead
zones

Farm
Animal
waste



Over-
Fishing

Food
Waste



World
Hunger

Forest
Clearing



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Glossary of Terms

Nomenclature

Bovine – of/relating to cattle, including but not limited to cows & calves

Poultry – of/relating to fowl, including but not limited to chicken & turkey

Porcine – of/relating to swine, including but not limited to pigs

(Conventional) Animal Agriculture – The modern, industrialized state of animal husbandry aimed towards the maximum production of animal-sourced products within primarily first-world nations

GHG – Greenhouse Gas (Emissions)

LCA – Life Cycle Analysis (Environmental assessment technique associated with all of the stages of a product's life)

Per-annum – per year

Cell-ag = Cellular Agriculture

NOAA - National Oceanic and Atmospheric Administration

IPCC – Intergovernmental Panel on Climate Change

NeOmnivore – one who only consumes (economically) cellular agriculture based animal products

Units

Gm³– Gigameters cubed (volume)

Kilogram (ℓ) – kilogram liquid (water)

m² – meters squared (area)

CO₂-eq - Carbon Dioxide – equivalent (emissions/gases)

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I

Introduction



Humanity's interest towards animal-sourced products spans millennia, yet in only the past decades has animal agriculture reached enormous capacity worldwide. Globally, over one trillion animals are raised & killed for food per year, creating an unparalleled shift over the last century in resource allocation towards non-human animals.^{1,2}

This shift has called for ecological costs locally and globally from water, land, and energy, to the result of their mere existence intrinsically producing greenhouse gas emissions (GHG) and biological waste.

Indeed, agricultural animals have always required these aforementioned environmental prerequisites to survive, but only recently have practices within animal agriculture rapidly changed towards systems which serve as a conduit for problems, such as containing animals in close quarters. Recent analyses have indicated a new-found ecological salience for large-scale animal husbandry. LCA of products within animal agriculture and international governmental data culminated in the past decades to shed light on the problems at hand, specifically environmental areas of concern from animal husbandry. This compendium will primarily address three such environmental categories: Water, Land, and Greenhouse Gas Emissions.

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III

Conventional Agriculture



The aforementioned trichotomous nexus of environmental harms of animal agriculture will be explored at greater length and categorically throughout this report, though the following statistics act as a primer towards these issues focusing on water, land, and greenhouse gas emissions:

Global animal agriculture requires about 242 Gm³ of water per annum, with the majority delegated towards water for the crops that animals consume.³ To put this figure into context, it has been calculated by the U.S. government's

National Geophysical Data Center at the NOAA that there is approximately 1.34 Gm³ of water in the ocean.⁴ This suggests that,

“In a single year, animal agriculture uses more water than there is contained in the entire Atlantic Ocean.”

Additionally, livestock now uses 30% of Earth’s entire land surface, with 70% of former forests in the Amazon having been turned over to grazing lands in the early 2000s.⁵ This utilization of arable land for animal agriculture is destined to cause a disastrous tension between expanding human populations in the coming decades and the land delegated towards crop production for livestock, which to make matters worse, will be increasing.

The meat, egg, and dairy industries account for 65% of worldwide nitrous-oxide emissions.³ Often figures like this have been aggregated to include only animal protein production industries, but widening the magnification to include all of animal agriculture, only amplifies concerns.

Animal agriculture, *including* other animal product industries (commonly left out of calculations) like leather, seafood, and wildlife products, emitted over **8 billion tons of CO₂-eq** in 2005.⁶ This is a notably conservative

figure since meat consumption has risen since 2005, and yet this quantity of total CO₂-eq from animal agriculture signifies over *15% of all greenhouse gas emissions globally*.⁶

To put this figure into context, all of the greenhouse gas emissions globally total to ~54 Billion tons of CO₂-eq, and according to the IPCC, there is just under 500 billion tons of Earth's carbon budget left.⁷ Exploring the consequences of reaching this “point of no return” for the carbon budget, is not within the scope of this report, though it is quite evident that global temperature increases from such “trespass” will come at a great cost to human civilization.

Regardless, the 15% of greenhouse gas emissions from animal agriculture, may be substantial in foreshadowing this potential carbon climax, and the following potential scenario aims to illustrate that:

As an ostensibly optimistic assumption, assume the energy sector, which accounts for the majority of carbon emissions, is completely transformed over the next decade and by the year 2025 the global energy sector emits “0” net carbon – quite a victory this would seem to be -- though unfortunately it will

not be. This would leave humanity with about 68 Billion tons left in the carbon budget upon the year 2025 in the scope of this hypothetical scenario, and total yearly emissions from animal agriculture would be increasing from the conservative figure of ~8 Billion tons. Therefore,

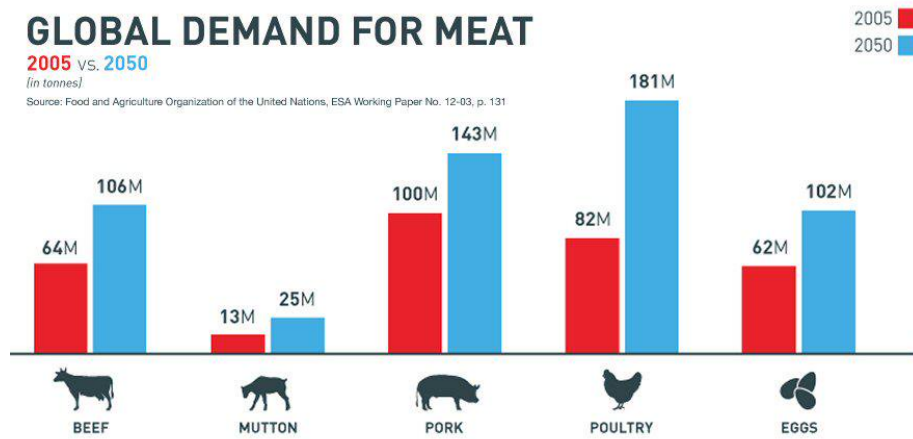
“ If by the year 2025, greenhouse gas emissions came only from animal agriculture alone, the ‘climate change threshold’, CO₂-eq maximum limit, would be reached by the year 2032, exclusively from the production of animal products.”

The problem becomes exponentially worse when considering global population is predicted to rise to 9.6 billion by 2050 and a corresponding 78%+ demand in animal proteins will ensue.⁶ While that may seem distant in time frame or even non-significant, juxtapose this scenario with the reality that in only 15 years from the publishing of this compendium (2017), livestock farming *alone* will bring us to a “no-turning back point” ecologically, making modern human existence on planet Earth a potentially impossible challenge.

GLOBAL DEMAND FOR MEAT

2005 vs. 2050
(in tonnes)

Source: Food and Agriculture Organization of the United Nations, ESA Working Paper No. 12-03, p. 131



Ultimately, these environmental impacts ought to act as an impetus for alternative animal agriculture in and of itself, though this impact is unbeknownst to most of the populace. The energy sector for instance, has viable alternatives (solar) already entering markets providing solutions with public consensus generally “on-board” that such alternatives are desired. Animal agriculture and its associated consumer base have stayed principally unaware of this environmental dilemma, and so the world seems unprepared to curb its vast consumption of animal-sourced products; let alone global veganism.

Understandably, this compendium has offered a pessimistic foreshadowing through the evidence presented thus far, however, an ecological solution may indeed be on the horizon, which in its transition can alleviate all of these environmental problems amongst others.

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III

Mitigation via Cellular Agriculture



As illustrated in the previous chapters, raising animals within the agricultural sector is causing significant environmental detriment, though perhaps,

**“the solution is found within the animals *themselves*...
... within their cells.”**

A growing biotechnological field called **cellular agriculture** aims to produce animal products without animals, by using animal cells to produce animal products, rather than entire organisms. This axiomatic shift in animal product creation from macro (organisms) to micro (cells) strives towards the production of items that consumers' desire, without the undesirable ecological impact. By removing the organism from the animal-agricultural equation, it will be possible to decrease environmental impact of animal products on a revolutionary scale.

Without extensive scientific description, Cell-ag is predicated upon the assumption that the constituents of animals as biological organisms are cells fundamentally. These constituents, in smaller ratio of the whole organism, will require less resources than the entirety of such organism -- a sort of a la carte manner of thinking, but in an effort to decrease resource dependence. Similar deductive logic is exercised habitually, assuming a larger person requires more energy input to survive, or even when watering plants, it is assumed that two plants require more water than one. And so, since a chicken for instance, requires fresh water daily to nourish all of the cells/tissues in its body, and the

muscle of its body requires less than all of the other cells, less resources are needed proportionally. The advantage of cellular agriculture is that this proportionality happens to be an iota when put up for comparison.

This is certainly an oversimplification of the scientific basis and environmental prospects of Cell-ag, but ought to act as a useful precursor to this compendium and general guide in understanding the basis for the following ecological analyses.

The following chapters will offer comprehensive analyses on the environmental advantages of cellular agricultures through independent animal product evaluations, with notes on areas of research not yet completed, and corresponding extrapolations towards hypotheses.

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IV

Bovine Meat



Bovines are the most environmentally injurious ruminants, and animals, overall, in this report, contributing significantly to the overall damage animal agriculture entails ecologically. Bovine characteristics that grant them this level of impact are their ruminant basis for digestion, and general large size over other livestock animals. The following are environmental costs of producing conventional bovine meat products in contrast to cellular agriculture analogs:

Water

Approximately 15,415 liters of water are required per kilogram of bovine meat produced.⁹ This is the equivalent of about 20 years of drinking water for the average person.^{9, 10}

Cellular agriculture meat is estimated to require about 332 liters of water per kilogram produced.⁸ This estimate is an average based upon the “best” and “worst case” propensity for error of wheat cellular media utilization. Cellular agriculture meat therefore, would require 98% less fresh water than conventional bovine meat.^{8, 9}

Land

Bovine meat requires the most arable land considering the grazing area they encompass, more common within the cattle industry. Bovine meat requires about 400 m²/kg of land with crop space, manufacturing, and all corresponding terrestrial acreage accounted for in such calculus.¹¹

Cellular agriculture meat is estimated to require about 2.7 m² per kilogram produced.⁸ This estimate is based upon conservative figure acquisition referencing the most land-occupying cellular media. Cellular agriculture meat is estimated to require 99% less land than conventional bovine meat.^{8, 11}

Greenhouse Gas Emissions

The production of bovine meat contributes 2.495 billion tons of CO₂-eq annually accounting for 41% of the total greenhouse gas emissions from livestock.⁶ The main sources of such emissions are the enteric fermentation processes from the digestion of bovine animals, and the fertilization for feed.⁶

Cellular agriculture meat is estimated to contribute 96% less Greenhouse Gas Emissions than conventional Bovine meat, including auxiliary production/manufacturing processes.^{6, 8} Total annual greenhouse gas emissions from cellular agriculture meat would total to approximately 99,800,000 tons CO₂-eq.^{6, 8}

Key



Points

Cellular



98%
less water

Agriculture



99%
less land

Bovine Meat



96%
less GHG

will use...

- Chapter -

V

Bovine Leather



Bovine Leather has similar impacts to that of meat, however different manufacturing processes of tanning products for instance, incur varied ecological outputs. The following are the environmental costs of producing conventional bovine leather products in contrast to cellular agriculture analogs:

Water

About 17,093 liters of water are required per kilogram of bovine leather produced.⁹ This is the equivalent of about 23 years of drinking water for the average person.^{9,10}

Estimates on the prospective water footprint of Cellular agriculture leather produced via bio fabrication are not yet available. This stands as an important research area within the field of cellular agriculture for future exploration. The basis, however, for estimates of lowered fresh water use for cellular agriculture leather can be found in the Author's Notes.

Land

The following area estimation is based upon the datum that most of agricultural land requirements in animal agriculture are for crop production, and bovine leather animals and bovine meat animals consume similar quantities of such crops. Therefore, Bovine leather requires about 400 m²/kg of land with

crop space, manufacturing, and all corresponding terrestrial acreage accounted for in this calculus.¹¹

Estimates on prospective land usage of Cellular agriculture leather produced via bio fabrication are not yet available. This stands as an important research area within the field of cellular agriculture for future exploration. The basis, however, for estimates of lowered land use for cellular agriculture leather can be found in the Author's Notes.

Greenhouse Gas Emissions

Figures on greenhouse gas emissions of leather are notably difficult and even with conventional products existing throughout much of history, PCF (Product Carbon Footprints) have not been completed, with high certainty at least. However, excluding variables like thickness of material, the following is a postulation towards such a figure:

According to the FAO, 6,446.2 thousand tons of leather were produced in 2012.¹² Notably, this was the production of “Bovine Hides and Skins”, excluding other animals like goats and sheep which leather is made from as well. This exclusion within this compendium has been made in the following estimate since the cellular agriculture analog currently in production for leather is focused on bovine replacement since the bulk of leather production is indeed from bovine animals.

It is also estimated that 2.2 kg of CO₂-eq is the carbon footprint per kg of leather.^{13, 14} These two figures, in conjunction, suggest that 156.3 million tons of CO₂-eq are contributed from the leather industry annually.^{12, 13, 14}

Estimates on prospective greenhouse gas emissions of Cellular agriculture leather produced via bio fabrication are not yet available. This stands as an important research area within the field of cellular agriculture for future exploration. The basis, however, for estimates of lowered greenhouse gas emissions for cellular agriculture leather can be found in the Author’s Notes.

- Chapter -

WMI

Bovine Dairy



Bovine Dairy has similar impacts to that of meat and leather, however different manufacturing processes like fermentation within the industry incur varied ecological outputs. The following are the environmental costs of producing conventional bovine dairy products in contrast to cellular agriculture analogs:

Water

Due to the varied products derived from Bovine dairy, the fresh water footprint of products vary depending on factors like manufacturing requirements and production time. 5,553 liters of water are estimated to be required per kilogram of butter, 3,178 liters of water per kilogram of cheese, and 1,020 liters of water per kilogram (ℓ) of milk.⁹ Considering these three dairy products, they average to require about 3,250 Liters of fresh water per kilogram of dairy product produced, which is the equivalent of about 4 ½ years of drinking water for the average person.^{9,10}

Cellular agriculture dairy is estimated to require about 20 liters per kilogram produced.¹⁵ This estimate is an average based upon the three aforementioned dairy products, and signifies cellular agriculture dairy will require 99.6% less fresh water than conventional cellular agriculture dairy.^{9,15}

Land

Bovine dairy, considering its encompassing nature, requires varied quantities of arable land. Bovine milk requires about 2 m²/kg (ℓ), while cheese requires about 17 m²/kg, therefore bovine dairy will be averaged as an inclusive term, to require about 10 m²/kg of land with crop space, manufacturing, and all corresponding terrestrial acreage accounted for in this calculus.¹¹

Cellular agriculture dairy is estimated to require about 0.27 m²/kg (ℓ) produced.¹⁵ Therefore, cellular agriculture dairy is estimated to require about 97% less land than conventional bovine dairy.^{11, 15}

Greenhouse Gas Emissions

2.128 billion tons of CO₂-eq are emitted from conventional dairy systems annually.⁶ This serves as 20% of the total that animal agriculture contributes to in regards to anthropogenic greenhouse gas emissions and about 5% of all greenhouse gas emissions annually.⁶

Cellular agriculture dairy is estimated to contribute 65% less Greenhouse Gas Emissions than conventional dairy systems, including auxiliary production/manufacturing processes.¹⁵ Total annual greenhouse gas emissions from cellular agriculture dairy would total to approximately 744,800,000 tons CO₂-eq if the same amount of dairy were to be produced from Cell-ag systems.¹⁵

Key



Points

Cellular



99.6%
less water

Agriculture



97%
less land

Bovine Dairy



65%
less GHG

will use...

- Chapter -

VIII

Poultry Meat



Poultry meat is of varied impact than bovine products, though the lack of size that poultry have over bovine is often reconciled with the quantity in which poultry animals are bred. The following are the environmental costs of producing conventional poultry meat products in contrast to cellular agriculture analogs:

Water

Production of conventional poultry meat requires approximately 4,325 liters of water per kilogram, which is the equivalent of about 6 years of drinking water for the average person.^{9, 10}

Cellular agriculture meat is estimated to require about 332 liters per kilogram produced.⁸ This estimate is an average based upon the “best” and “worst case” propensity for error of a utilized wheat cellular media, and signifies cellular agriculture meat requiring 92% less fresh water than conventional poultry meat.^{8, 9}

Land

Poultry meat requires about 7 m²/kg of land with crop space, manufacturing, and all corresponding terrestrial acreage accounted for within this calculus.¹¹

Cellular agriculture meat is estimated to require about 2.7 m²/kg.⁸

This estimate is based upon conservative figure acquisition referencing the most land-occupying cellular media. Therefore, Cellular agriculture meat is estimated to require 66% less land than conventional poultry meat.^{8,11}

Greenhouse Gas Emissions

Conventionally produced poultry meat contributes about 389 million tons of CO₂-eq per annum, with the main sources of emissions being feed production, specifically fertilization, and the use of machinery and transport.⁶ Poultry collectively (meat and eggs) contribute 612 million tons of CO₂-eq annually, with 64% from meat production, and 36% from egg production.⁶ In total, poultry contribute 8% of the total emissions from the livestock sector, with meat contributing about 5% and eggs about 3%.⁶

Cellular agriculture meat is estimated to contribute 74% less Greenhouse Gas Emissions than conventional Poultry meat, including auxiliary production/manufacturing processes.^{6,8} Total annual greenhouse gas emissions from cellular agriculture meat would total to approximately 99,800,000 tons CO₂-eq.⁸

Key



Points

Cellular



92%
less water

Agriculture



66%
less land

Poultry Meat



74%
less GHG

will use...

- Chapter -

VIII

Poultry Eggs



In contrast to other animal-sourced goods poultry eggs are currently an animal product predicated upon change, since the industry is shifting towards alternative methods of production such as “cage-free” containment methods for hens. Nevertheless, the following are the environmental costs of producing conventional poultry eggs in contrast to cellular agriculture analogs:

Water

About 3,300 liters of fresh water are required for the production per one kilogram of poultry eggs.⁹ This is the equivalent of about 4 ½ years of drinking water for the average person.¹⁰ This water footprint of poultry eggs also equates to about 200 liters of fresh water per one egg (~60g) produced.⁹

Estimates on the prospective water footprint of Cellular agriculture egg whites produced via fermentation are not yet available. This stands as an important research area within the field of cellular agriculture for future exploration. The basis, however, for estimates of lowered fresh water use for cellular agriculture poultry eggs can be found in the Author's Notes.

Land

Poultry eggs require about 7 m²/kg of land with crop space, manufacturing, and all corresponding terrestrial acreage accounted for in this calculus.¹¹

Estimates on the prospective land usage of Cellular agriculture egg whites produced via fermentation are not yet available. This stands as an

important research area within the field of cellular agriculture for future exploration. The basis, however, for estimates of lowered land usage for cellular agriculture poultry eggs can be found in the Author's Notes.

Greenhouse Gas Emissions

Conventionally produced poultry eggs contribute about 217 million tons of CO₂-eq per annum, with the main source of emissions being feed production, specifically fertilization, and the use of machinery and transport.⁶ Poultry collectively (meat and eggs) contribute 612 million tons of CO₂-eq annually, with 64% from meat production, and 36% from egg production.⁶ In total, poultry contribute 8% of total emissions from the livestock sector, with meat contributing 5.12% and eggs 2.88%.⁶

Estimates on the prospective GHG of Cellular agriculture egg whites produced via fermentation are not yet available. This stands as an important research area within the field of cellular agriculture for future exploration. The basis, however, for estimates of lowered GHG for cellular agriculture poultry eggs can be found in the Author's Notes.

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IX

Porcine Meat



As the most damaging non-ruminant animal products in this compendium, porcine meat causes environmental woes in part, attributed to their position as the largest non-ruminant livestock animal in this report. The following are the environmental costs of producing conventional porcine meat products in contrast to cellular agriculture analogs:

Water

Production of conventional porcine meat requires approximately 5,988 liters of water per kilogram, which is the equivalent of about 8 years of drinking water for the average person.^{9, 10}

Cellular agriculture meat is estimated to require about 332 liters per kilogram produced.⁸ This estimate is an average based upon the “best” and “worst case” propensity for error of a utilized wheat cellular media, and signifies cellular agriculture meat requiring 95% less fresh water than conventional porcine meat.^{8, 9}

Land

Porcine meat requires the most land of the non-ruminants. Porcine meat requires about 15 m²/kg of land with crop space, manufacturing, and all corresponding terrestrial acreage accounted for in this calculus.¹¹

Cellular agriculture meat is estimated to require about 2.7 m² per kilogram produced.⁸ This estimate is based upon conservative figure acquisition referencing the most land-occupying cellular media. Therefore, Cellular

agriculture meat is estimated to require 82% less land than conventional porcine meat.^{8, 11}

Greenhouse Gas Emissions

The production of porcine meat contributes 668 million tons of CO₂-eq annually which accounts for 9% of the total greenhouse gas emissions from livestock.⁶ The main sources of these greenhouse gas emissions are feed production and management/containment of manure from porcine.⁶

Cellular agriculture meat is estimated to contribute 85% less Greenhouse Gas Emissions than conventional porcine meat, including auxiliary production/manufacturing processes.^{6, 8} Total annual greenhouse gas emissions from cellular agriculture meat would total to approximately 99,800,000 tons CO₂-eq.⁸

Key



Points

Cellular



95%
less water

Agriculture



82%
less land

Porcine Meat



85%
less GHG

will use...

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X

Seafood



Seafood, or fish meat, for the sake of this report, causes issues environmentally that go beyond the scope of this compendium chiefly focusing upon land, water, and GHG. Though collectively, this group of animal products is an environmental detriment terrestrially and the nexus of water, land, and GHG indeed encompasses that. The following are the environmental costs of producing seafood products in contrast to cellular agriculture analogs:

Water

Utilizing an estimate that 390 km³ of fresh water is used per annum on seafood acquisition and the UN statistics on annual fish catch (in tonnage) it can be approximated that 2,337 Liters of water are required per kilogram of seafood produced.^{16,17, 19} This is the equivalent of about 3 years of drinking water for the average person.¹⁰

Cellular agriculture meat is estimated to require about 332 liters per kilogram produced.⁸ This estimate is an average based upon the “best” and “worst case” propensity for error of a utilized wheat cellular media, and signifies cellular agriculture meat requiring 86% less fresh water than conventional poultry meat.^{8, 16, 17}

Land

Seafood land usage is variable as it must be split categorically into the dichotomy of aquaculture and wild catch systems. The unit system for land in this report is based upon 2-dimensional space, which of course would not properly accommodate for the canonical, 3-dimensional figures of ocean

volume via m^3 . Consequentially, statistical figures are indeed often riven for wild catch and aquaculture, and hence, the latter will act as the focal point for seafood with respect to land usage. It is estimated that seafood requires about $6 m^2/kg$ of area with manufacturing, and all corresponding terrestrial/oceanographic acreage accounted for in this calculus.¹¹

Cellular agriculture meat is estimated to require about $2.7 m^2$ per kilogram produced.⁸ This estimate is based upon conservative figure acquisition referencing the most land-occupying cellular media. Therefore, Cellular agriculture meat is estimated to require 55% less land than conventional seafood.^{8, 11}

Greenhouse Gas Emissions

Figures on greenhouse gas emissions for seafood are conspicuously problematic, and even with conventional products existing for long periods, PCF (Product Carbon Footprints) have not been completed, with high precision at the least. However, the following is an estimate that has been made in this report towards a postulation of such a figure, though it ought to be noted that the carbon emissions from seafood are complicated. For

example, cellular respiration from fish within the ocean, for instance, is in stark contrast environmentally, with carbon emissions from tankers in the ocean leading to varying effects atmospherically. Nevertheless, according to the FAO, 93.4 million tons of fish are caught annually in the wild and 48.1 million tons of seafood is farmed.^{16, 17} It is predicted that 1.7 tons of CO₂-eq are emitted per ton of seafood caught.¹⁸ With the figures of seafood caught collectively, and the carbon footprint estimation, it can be extrapolated that 240.55 million tons of CO₂-eq are contributed from the seafood industry annually.^{16, 17, 18}

Previous comparisons with particular seafood like Atlantic salmon, showed 40% lower greenhouse gas emissions of cellular agriculture meat over conventional seafood.⁸ However, utilizing the FAO statistics, this compendium finds cellular agriculture analogs will contribute 59% less Greenhouse Gas Emissions than conventional seafood, including auxiliary production/manufacturing processes.^{8, 16, 17, 18} Total annual greenhouse gas emissions from cellular agriculture meat would total to approximately 99,800,000 tons CO₂-eq.⁸

Key



Points

Cellular



86%
less water

Agriculture



55%
less land

Seafood



59%
less GHG

will use...

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XII

Wildlife Products



Wildlife products are not farmed in quantities akin to other animal products since primary means of consumer acquisition is poaching. However, microcosms of wildlife farming, do indeed exist and in turn, suggest environment damage. The following are the environmental costs of producing conventional wildlife products in contrast to cellular agriculture analogs:

Water

As will be completed for greenhouse gas emissions for rhinoceros, great calculative measures must be taken to approximate the water footprint of rhinoceros horn farming. The largest rhinoceros farm, purposed for rhinoceros horn acquisition, is in South Africa and contains 1,261 rhinoceros.^{23, 24} This will be the basis for comparison in this report, since the prospect of cellular agriculture rhino horn would eliminate the necessity to raise/breed this quantity of rhinoceros, with the exception of captivity and conservation efforts.

It must be noted that the water footprint from wildlife products are increasingly difficult to obtain since estimates of water footprint data from wildlife animals themselves do not even exist. The following is a postulation of such a figure with respect to rhinoceros and their horns since this is the only wildlife product that has a cellular agriculture analog in development:

The average human, vegan adult has a water footprint of approximately 350 gallons or 1,300 liters; it is critical to not attribute the same 29x factor that will be used in greenhouse gas emission analysis, and instead a more

conservative factor of 6x will be used since rhinoceros drink about 6 times more water than a vegan human daily.^{20, 21, 22} This is particularly conservative as the bulk of ones' water footprint comes from the water necessary to grow the crops they consume, and therefore the following figure is likely significantly more conservative than what ought to be attributed, but still large nevertheless.

The average lifespan of a rhinoceros is about 40 years and has been calculated to use about 116,060,364 liters of fresh water in its lifetime.²⁰⁻²⁴ It is also noted that in a rhinoceros' lifetime, about 55 kilograms of horn can be obtained.^{23, 24} These figures lead to the conclusion that 2,110,188.44 liters of fresh water are necessary per kilogram of rhinoceros horn produced.²⁰⁻²⁴ This is the equivalent of approximately 35 peoples' lifetime consumption of drinking water.^{10, 20-24}

Estimates on the prospective water footprint of Cellular agriculture rhinoceros horn are not yet available and as such, this stands as an important research area within the field of cellular agriculture for future exploration. The basis, however, for estimates of lowered fresh water use for cellular agriculture wildlife products can be found in the Author's notes.

Land

On the aforementioned rhino farm, it is noted that the area for the farmed animals in South Africa is about 8,000 hectares.^{23, 24} With 1,261 rhinoceros, this grants about 6.34 hectares of land per rhinoceros, which will produce about 55 kilograms of rhino horn in its lifetime.^{23, 24} Therefore, it can be extrapolated that 0.12 hectares land are required per kilogram of rhinoceros horn produced, or 1,200 m² per kilogram.²¹⁻²⁴

Estimates on the prospective land usage of Cellular agriculture rhinoceros horn are not yet available. This stands as an important research area within the field of cellular agriculture for future exploration. The basis, however, for estimates of lowered land use for cellular agriculture wildlife products can be found in the Author's Notes.

Greenhouse Gas Emissions

As was noted, ecological figures on wildlife products are challenging since even with conventional products existing for long periods, PCF (Product Carbon Footprints) have not been completed, with high certainty at the least.

It must be noted that the carbon emissions, specifically from wildlife products are increasingly difficult to obtain since estimates of carbon emissions from wildlife themselves do not even exist. The following is a postulation of two such figures with respect to rhinoceros and their horns since this is the only wildlife product that has a cellular agriculture analog in development:

The average human adult weighs 137 pounds and consumes approximately five pounds of food daily.²⁰ Coincidentally, a factor of 29_x accurately places average human weight (137 lbs) with average rhinoceros weight (4,000 lbs), and average human nutritional intake (5 pounds) with average rhinoceros nutritional intake (145 pounds).^{20, 21} Since estimates do not exist as to the carbon footprint of rhinoceros, there is a necessity for extrapolation upon these figures with carbon footprint estimates of adult humans. However, the carbon footprint that a vegan human contributes must be used since rhinoceroses are herbivores and their diets' carbon footprint will reflect such footprint more similarly.

The average vegan adult contributes 2.89 kg CO₂-eq per day, and so with the aforementioned 29_x factor, in addition to unit calculus, it can be

estimated that the average adult rhinoceros emits 30,798 kg/CO₂-eq per day.^{20, 21, 22} Utilizing the 30,798 kg/CO₂-eq per rhino daily figure, in conjunction with the farm statistics, it can be concluded that annual rhinoceros horn farming contributes at least 42,809.67 tons of CO₂-eq globally.²⁰⁻²⁴

Estimates on the prospective GHG of Cellular agriculture rhinoceros horn are not yet available. This stands as an important research area within the field of cellular agriculture for future exploration. The basis, however, for estimates of lowered GHG for cellular agriculture wildlife products can be found in the Author's Notes.

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XIII

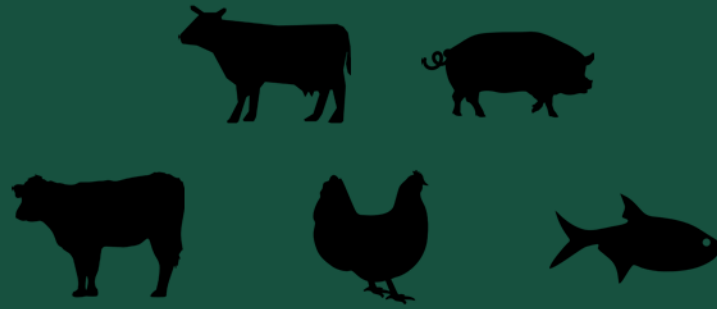
Conclusion



If humanity is to evade the worst effects of climate change, land & fresh water scarcity, among other consequences of mass animal husbandry, a viable alternative must be introduced expediently. As has been extensively outlined in this compendium, cellular agriculture will significantly alleviate the pressure that is currently placed on greenhouse gas, fresh water, and land resources.

The environmental influence of this production shifts towards cellular agriculture, specifically fermentation and tissue engineering, to produce animal products, in lieu of animal farming & slaughter would be of a magnitude never before seen on Earth, and such a manufacturing evolution could not come a moment sooner.

Key



Points

Cellular



94%
less water

Agriculture



80%
less land

Products



76%
less GHG

will use...

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Author's Notes



Cellular
Agriculture
Society

For the people For the animals

For the world

- The foundational principle of cellular agriculture's environmental benefits remains that tissue engineering techniques and fermentation are indeed carried out today, and so it seems exceptionally unlikely that these methods of future animal agriculture would rival the current exorbitant necessity for resources in conventional animal agriculture. It is also reasonable to assume that Cell-ag media (the equivalent of "feed") will be an iota less in quantity.
- An additional argument is that since animal agriculture seems to be the worst cause of environmental harm in its current state of methodology, it is reasonable to assume that a new method (Cell-ag), regardless of its nature, is likely, logically, to be less damaging. This does not indeed serve as a conclusive argument, though is quite cogent nevertheless.

- This literature serves as the first introduction of the word, **Neomnivore**, a term that I coined to express the difference between a “vegan”, “omnivore”, and one who only consumes cellular agriculture products. To paint a picture for greater elucidation, imagine someone is in a restaurant in the year 2040, and they only consume animal products made via cellular agriculture. In trying to describe their dietary habit to the waiter/waitress, they would struggle utilizing a term like omnivore or meat eater, since they are not indeed a traditional meat eater, and nor an alternative consumer like a pescatarian. They would also be false in claiming to be “vegan”, which is one who does not consume animal products whatsoever. Rather, they would simply state that they are a “Neomnivore”, or one who only consumes animal products from cellular agriculture (with consumption indicating consuming products as a consumer within an economy). The inspiration for the term “neomnivore” came from an interest to label this philosophy back in 2016, analyzing terms in this space, and finding something that could accurately and metaphorically illustrate this future concept. When noticing the prefix “Neo-” suggests “new” and “Omnivore” of course is one who indeed consumes animal products, the “o” at the end and beginning of the words, respectively, merged, forming the term “*NeOmnivore*”, and its corresponding philosophy, “Neomnivorism”. Suggestions for nomenclature in other languages are certainly welcomed or even a better term perhaps in lieu of Neomnivore. Regardless, this compendium urges future members of society who may find it too difficult to go vegan or vegetarian, to instead go Neo/Neomni when possible.

- This compendium is structured such that updates to the statistics can be made as technologies advance, commercialize, and more valid ecological comparisons can be made.
- It has been noted that a commercial entity based upon cellular agriculture dairy will be completing an updated ISI Compliant LCA in 2018.
- It has been noted that a commercial entity based upon cellular agriculture egg whites will be completing its first LCA likely before the next version of this compendium is released.
- To segue from these last two points, more critically than analyses in this report, will be LCAs conducted on individual prototypes independently.
- Preference was given to FAO figures on GHG emissions over (Nijdam, et al. 2012) considering time frame of study, though it did indeed serve as primary source for land-related statistics, in conjunction with (Tuomisto, 2014).
- All water statistics are based upon global average water footprints, primarily sourced from waterfootprint.org

- LCAs will obviously be necessary to make direct “meat per meat comparisons”, and until this can be completed upon product commercialization, precise figures on this subject will be a calculative impossibility.
- The environmental LCAs for cellular agriculture products outlined in this report are also predicated upon nascent methods; it is highly likely that with cellular agriculture products, like most technologies, innovation and optimization of processes over years will heighten the environmental savings expressed in this study, particularly when doing so will be financially advantageous for the corporation.
- Much of the analyses within this compendium contain various caveats; for instance, in Europe, about 80 percent of the beef is produced from dairy animals (surplus calves and culled cows), resulting in lower emission intensities than other nations without such methodology.
- Strong consideration also ought to be given to this report’s dependence on figures from nations which vary in their animal husbandry methods, ultimately making predictions difficult.
- This report uses statistical inferences made on behalf of companies and academics, and the majority of the calculus done used percentage reduction estimates from LCAs and published environmental impact research. Such

percentages were held against baseline figures obtained from the 2013 FAO report.

- Considering the various ways in which to farm animals, to obtain animal products, modern industrialized animal husbandry remains the optimal method of production (its greatest utility, economically), though a problematic cause of environmental stress. Therefore, it is reasonable to assume following similar analyses, that pre-LCA products in cellular agriculture would have reduced environmental impact
- As has been likely noted to a fault here in these notes, statistics are complicated in coming to strong conclusions on cellular agriculture method transition. For instance, 66,138,678,655 pounds CO₂-eq of fishmeal goes to livestock. Assuming cellular agriculture fish were to replace conventional fish, this number would still disappear as the livestock whom would be consuming this fishmeal would no longer exist. This is just one example of the intertwined nature animal agriculture plays, posing challenges in this compendium.
- Other animals like buffalo and smaller ruminants comprise a portion of the total greenhouse gases, though are un-noted in this report. Such omission was intentional as there are no cellular agriculture analogs for these products in development, so no impending comparisons seemed reasonable to make. However, upon future reports, if progress is made on these fronts (as I predict it will), additional chapters ought to be added to this compendium.

- Thank you for reading -

To learn more about cellular agriculture please visit

www.CellAg.org

Christopher Pastore

THIS REPORT IS THE FIRST OF DECADES LONG-WORK THAT WILL TAKE PLACE ON THE TOPIC OF CELLULAR AGRICULTURE, AND THEREFORE IS SUBJECT TO SIGNIFICANT ALTERATION FROM THIS FIRST SUBMISSION IN 2017.

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