**Technical assessment for**

**Managed Grazing**

Sector: Food

Agency Level: Rancher/Pastoralist

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# Executive Summary

Project Drawdown defines *managed grazing*as: a set of practices that sequester carbon in grassland soils by adjusting stocking rates, timing, and intensity of grazing. This solution replaces conventional grazing on grasslands, including both pastures and rangelands.

Livestock grazing covers over 2.7 billion hectares, some 25 percent of the world’s land area, making it humanity’s largest land use. Poor grazing practices have contributed to land degradation and loss of soil carbon. However, *managed grazing*practices can enhance net carbon sequestration on grazing lands.

Under *managed grazing*, emissions of the greenhouse gases methane and nitrous oxide continue, but are more than offset by sequestration, at least until soil carbon saturation is achieved. Drawdown takes the conservative assumption that emissions do not change with conversion from conventional to *managed grazing*.

Under the projected *Plausible* Scenario, total adoption is 421.52 million hectares in 2050. The sequestration impact of this scenario is 14.85 Gt CO2-eq by 2050. Cumulative first cost is US $30.69 billion, with a net profit margin of US$639.15 billion. Under the *Drawdown* Scenario, total adoption is 757.28 million hectares in 2050. The sequestration impact under this scenario is 32.10 Gt of CO2-eq by 2050. Cumulative first cost is US $61.28 billion, with net profit margin of US$1,431.39 billion. Under the *Optimum* Scenario, projected total adoption is 780.50 million hectares in 2050. The sequestration impact under this scenario is 34.57 Gt of CO2-eq by 2050. Cumulative first cost is US $63.65 billion, with net profit margin of US$1,558.91 billion.

Though these results are more modest than some claims that have been made on behalf of this solution, managed grazing nonetheless has an important role to play in climate change mitigation on the world’s vast grasslands.

# Literature Review

## State of the Practice

Managed grazing as defined here is a suite of practices that modify the intensity of grazing a specific piece of grazing land, rest an area of grazing land by excluding livestock for a period of time, and/or rotate livestock into and out of paddocks or pastures. Climate impact is via carbon sequestration. Emissions of CH4 and NO2 continue relatively unabated. This practice is distinct but connected to climate impacts from pasture management (seeding of legume fodders, fire management, irrigation, etc).

Grazing lands include pastures (intentionally planted and sometimes irrigated and fertilized) and rangelands (naturally-occurring grasslands, neither fertilized nor irrigated). The agents that manage grazing on these lands are sometimes called graziers, and includes ranchers (grazing on land they own or rent) and pastoralists, who practice nomadic and *transhumance* grazing on communal and other lands (Johnsen 2019).

Managed grazing is an ancient practice, for example *Al Hima* grazing goes back 1,400 years on the Arabian Peninsula (Kilani 2007). Managed grazing was formerly more widespread than it is today. For example, when the former Soviet Union collectivized lands in Central Asia, it interrupted traditional pastoralist practices resulting in the degradation of vast areas of grasslands (Kerven 2006).

Worldwide there are a number of managed grazing practice including but not limited to:

* **Continuous grazing with improved stocking rates or seasonality of grazing** to avoid overgrazing or undergrazing. Adoption rates for this approach are harder to come by because it is not necessarily practiced as a formalized strategy.
* **Deferred grazing,** a period of rest without grazing within the midst of a grazing season (Howery 2000).
* **Resting,** a full 12 months without grazing (Howery 2000).
* **Rotational grazing**, in contrast to continuous grazing, calls for regular movement of livestock to fresh paddocks or grazing areas to provide for pasture recovery, improve livestock health and production, and protect water quality.
* **Grazing optimization,** decreasing stocking rates in overgrazed areas and increasing them in undergrazed areas, resulting in increased productivity (Fargione 2018).
* **Adaptive Multipaddock (AMP) grazing** generally requires paddocks that are grazed 3 to 7 days and rested 25 to 35 days (*National Sustainable Agriculture Information Service 2004*). It also decreases the size of grazed areas, shortens the time the livestock are allowed on that area, and often increases the number or head of livestock on a farm (Heitschmidt and Taylor, 1991). Definitions of AMP sometime include other terms but very similar in practice (e.g. cell grazing, short duration grazing) or are associated with practices which are similar to or incorporate IRG within their grazing strategy. There are now several “schools” of thought that include a different sets of best management practices, notably “mob grazing” (Bittman and McCartney, 1994) and “Holistic Management” (HM) (Savory, 1999), which include rotational grazing but also feature other important strategies.

*Carbon Sequestration*

The climate impacts of managed grazing are much more complex than many other agricultural mitigation strategies. The same practice may lead to increase, decrease, or no change in soil carbon when practiced on different sites. Thus there is a need to determine management including grazing intensity for each climate and grassland type (Lorenz and Lal 2018). A review by Conant et al (2017) found that grazing management increased soil carbon in only 48.9% of studies.

Increasing or decreasing grazing intensity can increase total carbon depending on the location. Greater grazing intensity is usually thought to reduce soil carbon by lessening CO2 fixation from the loss of photosynthetic tissue and reduction in belowground C inputs through lower root production and higher root litter turnover (*Gao et al. 2008, Klumpp et al. 2009, Soussana et al. 2010*). However, grazing-induced changes in allocation of carbon belowground and change of root C:N is associated with positive effects of grazing on SOC (*Bardgett et al. 1998, Reeder & Schuman 2002*). In one study, no differences in C sequestration were found among short-duration rotational grazing, rotationally deferred grazing, and continuous season-long grazing at heavy stocking rates (Manley et al. 1995). Others have found that heavy grazing reduces total carbon in some grasslands (Smoliak et al. 1972, Dormaar et al. 1977) but increases it in other grasslands (Johnston 1961, Smoliak et al. 1972), with the most significant changes happening in the top 15 cm of the soil profile (Naeth et al. 1991).

Henderson (2015) developed a model that calculated that only 28% (711 Mha), of global grazing lands are actually amenable to carbon sequestration via management grazing. The study noted that if managed grazing were applied to all grazing lands regardless of amenability, it would result in net emissions.

Sequestration impacts may have as much to do with the initial condition of the grazing area than the grazing practice itself. Converting cropland to pasture can produce extremely high sequestration rates up to 8 t/ha/yr for the first 7 years, though yields from grazing are much lower than cropland (Machmuller 2015), so mass-conversion of cropland to grassland is not feasible. However this is a good option for cropland which is too steep or degraded to be suitable for cropping (agroforestry and perennial crops are also good options for such lands).

Several recent studies (e.g., Stanley 2018, Wang 2015) have shown higher sequestration rates between 3 and 4 t/ha/yr from sophisticated grazing systems like Adaptive Multipaddock Grazing (AMP).

There is no single grazing management approach proven to consistently result in soil carbon gains. Instead, grazers in different regions need to adopt different management strategies to mitigate greenhouse gas emissions based on local and regional site conditions. Without understanding local conditions, the same grazing management strategy may have inconsistent results across studies. Indeed, past studies comparing grazing to nongrazing scenarios found that grazing at light, moderate, and heavy stocking rates increased SOC compared to nongrazed exclosures (Smoliak et al. 1972, Schuman et al. 1999, Wienhold et al. 2001, Reeder & Schuman 2002, Frank 2004). Others found grazing to have a negative effect on soil C storage (Su et al. 2005, Pei et al. 2008, Zuo et al. 2008, Golluscio et al. 2009). Some researchers found that grazing does not affect soil organic matter (Lodge 1954, Johnston et al. 1971, Dormaar et al. 1977, *Nosetto et al. 2006, Raiesi & Asadi 2006, Shrestha & Stahl 2008*).

Researchers and graziers are striving to understand what factors account for the differences in carbon sequestration. Soil type, climate, and grassland composition (C3 or cool season versus C4 or warm season grasses) are among the factors being investigated.

A meta-analysis of 17 studies (McSherry & Ritchie 2013) sought to disentangle the reasons behind whether grazing would have positive or negative effects on soil organic carbon. The analysis found that grazing effects heavily depend on local site conditions and dominant grass species. They tend to be negative with increasing precipitation on finer soils and positive with increasing precipitation on coarser soils; positive on sites dominated by C4 grasses and negative on sites dominated by C3 grasses*.*

Frasier (2019) found that grazing management made a difference in soils high in clay and silt, but much less so in sandy soils.

Abdalla (2017) conducted a review of studies looking at the soil carbon impact of grazing intensity (one, but not the only, component of managed grazing). Meta-analysis found that high grazing intensity increased soil carbon in C4-dominated grasslands, while in C3 and mixed grasslands high grazing intensity reduced soil carbon. Climate was found to be a major variable as well, see Table 1.1. In moist warm climates, all grazing intensities increased soil carbon, while in moist cool climates all intensities decreased soil carbon. In dry warm climates only low intensity increased carbon, while in dry cool climates low and medium intensity increased carbon while data was unavailable for high intensity.

Table . Impact of grazing intensity on soil organic carbon by climate type. From Abdalla (2017).

From Abdalla (2017). “+” indicates an increase in soil carbon, “-” indicates a decrease

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Dry warm climate** | **Moist warm climate** | **Dry cool climate** | **Moist cool climate** |
| High grazing intensity | \_ | + | Data unavailable | \_ |
| Medium grazing intensity | \_ | + | + | \_ |
| Low grazing intensity | + | + | + | \_ |

Intensity of management is noted to be of special importance in grassland carbon sequestration (Lorenz and Lal 2018). There is a disparity between the beneficial impacts observed by ranchers and pastoralists and the studies that show little impact from these complex forms of managed grazing. Many researchers and graziers agree that this is because scientific studies try to exclude the adaptive role of the manager in order to test the impact of practices themselves, but it may be that the adaptive management itself a role of critical importance (Teague 2013).

Managed grazing may also effect soil inorganic carbon stocks (SIC). However it is not yet clear what management strategies will increase or reduce SIC in any given situation (Lorenz and Lal 2018).

*Carbon stocks and saturation*

As is the case with most terrestrial carbon sequestration, there is a limit to the amount of carbon that can be stored in grasslands via managed grazing. Estimates vary on the length of time over which carbon can be sequestered, which range from 10-50 years (Toensmeier 2016). A recent study by Lal (2018) estimates 30-50 years until grassland saturation. This is of great importance, because after saturation is completed, these grazing lands with return to being net sources of greenhouse gases due to emissions of CH4 and NO2.

Franzleubbers (2012) and Follet and Reed (2010) note that it is degraded and overgrazed grasslands that have the most potential to sequester carbon, because their stocks are far below the levels of saturation. Frasier (2019) found that soil texture (sand, silt, clay) has a major impact on saturation and thus potential carbon stocks.

*Greenhouse gas emissions*

Livestock production is responsible for 14.5% of anthropogenic emissions, 7.1 Gt CO2-eq/yr (FAO 2013). Ruminants in grazing systems produce 20% of livestock emissions, but produce only 4% of the protein from the livestock sector. One study estimated that globally, biosequestration from managed grazing could offset 20-60% of these emissions, though the study excluded higher yet peer-reviewed sequestration rates (Garnett 2017). Note that this does not mean that biosequestration cannot offset emissions on a given hectare of land – as is seen in multiple studies including Stanley (2018).

Confined ruminants actually have lower emissions per kilo of meat or milk produced when compared to grazed ruminants, because productivity is higher in confined systems. This includes emissions from production of feed crops (Swain 2017). However when carbon sequestration is incorporated in the LCA, livestock products from managed grazing can have a net sequestration impact (“negative emissions”), at least until soils become saturated with carbon. One study found that the emission per kilo of meat from AMP grazing were 9.6 kg CO2-eq/kg carcass weight, compared to 6.1 kg CO2-eq/kg carcass weight for feedlot beef. However when carbon sequestration was included, the grazed beef net emissions became negative: -6.6 kg CO2-eq/kg carcass weight. However, it took twice as much land to produce beef in the grazing system, which has undesirable implications for emissions from land use change (Stanley 2018). Another study estimated that once sequestration rates reach or exceed 0.68 t/ha/yr, managed grazing systems become emissions negative (Röös and Nylinder 2013).

The great majority of soil carbon sequestration studies only account for soil carbon and do not account for emissions of CO2, CH4, and N2O. As with the effect of increased grazing pressure on soil carbon, the effect of increased grazing pressure on CH4 and N2O emissions is very variable and depends on underlying soil and other site conditions. Some studies project a fall in CH4 and N2O emissions along with an increase in soil carbon sequestration as a result of reduced grazing pressure (Wang et al. 2014). Below we provide a quick literature review of these emissions within the context of improved grazing management.

### *Methane emissions*

There is generally some inefficiency and dietary energy loss in the process of ruminants converting plant biomass into animal protein (DeRamus et al. 2003). Inter-animal variability in emission rates when given similar feed and identical grazing conditions is likely genetic or related to differences in rumen microbial communities (Lassey et al). CH4 emissions in ruminants could potentially be reduced through nutritional changes, e.g. through the addition of ionophores, fats, use of high-quality forages, and increased use of grains, as explored in Drawdown’s *improved livestock feed* solution (Boadi et al. 2004, Grainger & Beauchemin 2011). Within the domain of managed grazing and improved pasture management, studies have been conducted to test whether methane emissions rates differ significantly based on changes in stocking rate or sowed pasture species (and their effects on forage quality). It has been shown that higher-quality fodder from well-managed rangelands and pastures can somewhat reduce enteric methane production (FAO 2009).

It has been suggested that reducing stocking rates could lead to a decrease in CH4 and N2O emissions (Howden et al. 1996). However, there is no guaranteed straightforward reduction in CH4 emissions rates per cow/per kilogram of body weight basis as a result of improved forage quality from adjusting stocking rates. Indeed, CH4 production may remain constant per kilogram of body weight despite variations in diet quality under a variety of grazing scenarios – rotational grazing (heavy/light) and continuous grazing (heavy/light) (McCaughey et al. 1997). Despite the use of improved pastures and diet quality in select instances, CH4 production and voluntary intake remained relatively constant, suggesting the difficulty of reducing CH4 production of livestock grazing on pastureland through changes in grazing management alone.

There could be ways to increase CH4 uptake in soil (Chen et al. 2011), for example shifting from heavy to light/moderate stocking rates could help restore soil sinks for CH4 and therefore help offset some of the CH4 emissions.

#### Nitrous oxide emissions

Nitrous oxide (NO2) emissions from grazed livestock are a significant source of this highly potent greenhouse gas (IPCC 2014). There is some evidence that managed grazing, and some additional tools, can reduce NO2 emissions from the world’s vast grazing lands.

One recent study indicates that managed grazing can reduce NO2 emissions by restoring degraded pastures. Chirinda (2019) found that degraded pastures emit more NO2 than healthy, well-managed pastures. In some cases, higher stocking rates may decrease rather than increase net N2O emissions by stimulating nitrogen cycling and offsetting any increases in N2O emissions (Wolf et al. 2010). Manipulating the timing and intensity of grazing—e.g. limiting grazing in autumn to 3 hours per day—has led to reduction in both N2O emissions and NO3 leaching losses from grazed pasture by about 40 percent in New Zealand (de Klein 2006).

The pasture grass genus *Brachiaria*, already planted on hundreds of Mha due to it’s productivity, produces natural nitrification inhibitors, reducing NO2 emissions from grazing systems (Subbarao 2009). Nitrification and urease inhibitors can also be sprayed on grazing land, representing another option for reducing NO2 emissions (Edmeades 2004).

*Debate and Controversy over Grazing’s Potential*

Few Drawdown solutions are as controversial as managed grazing, particularly the Holistic or AMP grazing practices. Some voices urge conversion to vegetarian diets to reduce methane emissions. Others encourage the greatly increased use of managed grazing practices, declaring this to the be most important or even only mitigation solution needed. Scientists themselves are divided over the potential of this solution (Garnett 2017).

Large claims by some proponents, however, such as that AMP can reverse desertification and global warming (such as the highly popularized talk, “How to green the world’s deserts and reverse climate change” by Alan Savory in 2013 in Long Beach, California on February 27, 2013), have been met with skepticism by many researchers who study carbon dynamics, grasslands ecosystems, and pasture management. The most forceful critique is perhaps provided by Briske et al (2013) which almost entirely refutes claims made by proponents of Holistic Grazing.

Recognizing the controversial debate and uncertainty, there may still be potential benefits of AMP even if they are more modest than the most vocal proponents have suggested. Manure and urine contain large amounts of critical plant macro and micro nutrients (e.g. nitrogen, phosphorus, potassium, calcium, magnesium etc.), seeds (both desirable and undesirable), and carbon. The deposition of the manure and urine tends to be better distributed over AMP paddocks compared with other practices such as extensive grazing practices with single point feeding and water locations which tend to promote “manure hotspots” and trampling, and feedlot operations where manure and urine can become a liability, a source of odor and pollution, and can require large and expensive manure handling equipment and labor (White et al., 2001; Peterson and Gerrish, 1995).

The physical disturbance of livestock on the health of an ecosystem is a point of controversy within the literature. According to one view it is potential harm that can degrade potentially already ecosystems such as cryptobiotic crusts (assemblages of soil microbes, plants, and fungi which are thought to fix nitrogen, sequester carbon, stabilize soil, change soil hydrological and solar heat fluxes). According to another view, the disturbance of soil my provide an important function which increases plant available water via water pooling (in depressions left from hooves), provide sites for grass reseeding, and, therefore, to eventually increase net primary productivity and diversity of pasture species. One study of AMP in North American pasture systems found that “hoof action from having a large number of animals on a small area for short time periods reduced rather than increased filtration” (Holececk et al., 2000).

The beneficial impacts of AMP has been supported by Teague et al. (2011) who found critical soil parameters to be improved with AMP including decreased penetration resistance, increased aggregate stability, higher SOC levels, greater fungal-to-bacteria ratio and greater water holding capacity. Research by Briske (2008, 2011), however, has found no significant differences in soil hydrology, pasture plant primary production, or animal production from studies in the U.S. between conventional and AMP practices. The empirical evidence for these benefits of AMP is still inconclusive. As mentioned earlier, many of the ecological benefits are likely to be highly dependent on biophysical, climatic, soil type, breed(s) of livestock, and integration of other practices. Rainfall conditions may be of particular importance especially for increased net primary productivity and carbon sequestration with much greater potential in wet or “mesic” environments compared with arid- and semi-arid environments (Briske et al., 2013).

However several recent studies (Stanley 2018, Wang 2015) have shown higher sequestration rates between 3 and 4 t/ha/yr from AMP grazing.

A review by Hawkins (2017) found no difference overall between Holistic Planned Grazing and continuous grazing. The study noted that there appeared to be more benefit in more humid climates, while in arid climates the variation in rainfall from year to year is far more important than management system.

*Can managed grazing replace confined livestock and still meet demand?*

Could grassfed meat and dairy replace confined ruminant livestock and meet global demand? Grazing currently supplies 13% of beef and other ruminant meats, and 6% of milk, totaling a global average of 1 gm of animal protein per person per day. This compared to the 27 gm of animal protein consumed by the average person today, and 50-60 consumed by Americans. Garnett (2017) reports that grassfed livestock could provide 7-18 gm of animal protein per person per day, though some AMP practitioners report impressive yield increases. Meeting all milk and ruminant meat demand from grazing land alone would thus require very high levels of demand reduction, land use change (deforestation for pasture), and/or very high increases in productivity of grazing land (Garnett 2017). Thus this solution has an important relationship with demand-reduction solutions like *Plant-Rich Diet* and *Food Waste Reduction.*

*Impacts on Yields*

Several studies referenced in Corsi (2001) found little difference in productivity at low stocking rates, but greatly increased yields in intensively rotational systems at high stocking rates, due to the impressive growth rate of C4 grasses in the tropical wet season. Corsi notes that in the wet season, in intensively rotational systems, stocking rates can reach 15 animal units per hectare, versus 0.9 for extensive systems. The stocking rate in the cooler season is reduced to 1.5-6 animal units/ha, still quite impressive. Corsi cites a number of studies showing greatly increase yields of dry matter, beef, and milk under intensive rotation in humid tropical Brazil. Other studies show much more modest increases, and sometime decreases.

## Adoption Path

### Current Adoption

Very little data is available about the current scale of adoption of managed grazing. This is surely complicated by the practice’s many subtypes. Polly Ericksen, Program Leader on Sustainable Livestock Systems for the International Livestock Research Institute, communicated to Drawdown that while they have appropriate protocols and methods, in the absence of funding this data is unavailable (email May 20, 2019).

* Johnsen (2019) reports that there are between 22-500 million pastoralists worldwide, which they define as practitioners of rotational grazing on rangeland.
* Current adoption of restoration of degraded pastureland in South America is estimated at 10 Mha (Sá 2016). This practice includes, but is not limited to, managed grazing.
* The Canadian census of agriculture reports that 69% of larger ranches report “some form of” rotational grazing (Rothwell 2005). Deaton (2005) reports 16-24% of Canadian ranchers have grazing management plans.
* The US Census of Agriculture (National Agricultural Statistics Service 2012 and 2017) reported 1.9 percent of ranchers practicing rotational or management intensive grazing in 2012 and 2.9% in 2017. No information on the size of these operations is included. If these percentages are applied to all 199 Mha (FAOStat 2019) of US grazing land, the figures would be 3.7 and 5.7 Mha respectively.
* Ann Adams, Executive Director of Holistic Management International, estimates 41.6 Mha globally based on data from their Certified Educators. (Adams, personal communication, May 18 2019)
* Bobby Gill of the Savory Institute reports that adoption of holistic management grazing was 16 Mha in 2009 at the founding of their Institute, and that 10.1 Mha has been added 2009-2018 as a result of their efforts (Gill, personal communication, June 5 2019).
* Organic grazing land is not necessarily managed grazing, but some data is available (See Table 1.2). Australia has 27 Mha in organic grazing land. (FiBL & IFOAM 2019) This is 21% of its total of 130 Mha of grazing land (FAOStat 2019).
* Overgrazing on China’s 400 Mha of grazing land has gone from 33% in 2007 to 16.8% in 2013, representing 64.8 Mha where grazing intensity has been optimized (Hua 2014), though some of this includes complete and permanent grazing exclusion.
* As of 2000, an estimated 0.5% of Australian graziers practiced cell grazing (McKosker 2000).

Table 1.2 Organic Grassland by Region

Data from Organic World 2019 and FAOStat

|  |  |  |  |
| --- | --- | --- | --- |
| **region** | **organic grazing land ha** | **total grassland area (FAO)** | **as a percent** |
| Africa | 82,700 | 258,176,731 | 0% |
| Asia | 1,000,000 | 576,195,078 | 0% |
| EU | 5,700,000 | 69,979,217 | 8% |
| Latin America | 4,900,000 | 182,676,000 | 3% |
| N. America | 1,400,000 | 366,610,001 | 0% |
| Oceania | 34,900,000 | 145,743,930 | 24% |
| **Global Total** | 47,982,700 | 2,700,000,000 | 2% |

### Trends to Accelerate Adoption

The IPCC has rated managed grazing as being easily adopted by ranchers and pastoralists, and in a high state of readiness for implementation (IPCC 2014). A survey in Costa Rica found that managed grazing was the most preferred livestock mitigation method in all zones of the country (Navarro 2015).

The market for grassfed beef (usually, but not always, produced in managed grazing systems) is increasing rapidly. Sales of US-produced grassfed beef have increased from $17 million USD in 2012 to $272 million USD in 2016 (SLM 2017).

Several certification systems verify and promote managed grazing products, including a new initiative from the Savory Center called *Land to Market* (Savory Center 2019).

### Barriers to Adoption

Adoption may be limited in developing countries due to barriers to adoption around cost of establishment and lack of knowledge about the system. Establishing fences and water supplies can be extremely expensive and may incur high opportunity costs for managers (Wang et al. 2011). Two studies, though, demonstrated that cost-share programs may significantly increase the likelihood that farmers adopt rotational grazing strategies[[1]](#footnote-1),[[2]](#footnote-2). Similarly, since some of these practices are particularly knowledge-intensive, peer-learning and extension services may be key in increasing adoption through educational outreach (Ostrom & Jackson-Smith 2000).

Both establishment costs and operating costs tend to be higher for managed grazing systems, though profitability is also typically higher than conventional grazing. This can be seen, for example, in the many case studies from WOCAT noted in the references. This is a barrier that needs to be overcome with assistance securing tenure and obtaining financing.

### Adoption Potential

Henderson (2015) sets a maximum potential extent of 712 Mha based on the area of grassland their model determined is amenable to biosequestration via managed grazing. Other studies, including Lal (2018) assume all grazing land is suitable for managed grazing.

As part of the Paris Agreement, each signatory country files an Intended Nationally Determined Contributions (INDCs) with their plans for mitigation and adaptation. Grasslands are mentioned in 50 out of the 194 national proposals, but specific commitments are rather difficult to find (Richards 2015) . Of the 33 countries with at least 10 Mha of grazing land (FAOStat 2019), only Brazil and Namibia set a specific target for grassland management. Brazil’s INDC proposes to restore 15 Mha of degraded grazing land, equal to 20% of the national grazing area (Federative Republic of Brazil 2015). Namibia likewise plans to restore 15 Mha of degraded grazing land, in this case 38% of national grazing area (Republic of Namibia 2015).

As part of the Bonn Challenge and New York Declaration on Forests efforts to restore 350 Mha of degraded land, several countries have pledged to restore degraded grasslands. Burkina Faso has committed to 135,000 ha (0.23% of national grassland), India has pledged 800,000 ha (2.97% of national grassland), and Georgia has committed to achieve sustainable management of 70% of its grasslands, a total of 679,000 ha (FAOStat 2019, IUCN 2019)

Costa Rica projects a 20-40% increase in 20 years; increasing managed grazing area by 1-2% per year (Navarro 2015). Colombia’s Bovine Cattle Nationally Appropriated Mitigation Action aims to implement improved grazing management of superior forages on 2.2 Mha (Durango 2017), 13 % of total national grazing area (FAOStat 2019).

The Savory Center, a holistic management organization, has a campaign to transition 1 billion hectares to AMP grazing. (Savory Center 2019).

Sá (2016) projects an increase in restoration of degraded pasture from 10 Mha in 2015 to 20 Mha in 2020.

The Mongolian government intends to reduce overgrazing of sheep from 25 million head in 2017 to 20 million in 2020 (Batzorig 2018).

## Advantages and disadvantages of Managed Grazing

The IPCC report *Climate and Land* rates improved grazing land management as having a moderate impact of 0.3-3.0 Gt CO2-eq/yr in 2030. They rate its adaptation potential as moderate, impacting between 1 and 25 million people. It’s potential to reverse desertification is rated medium, at 50 to 300 Mha, while its potential to address land degradation is rated large with an impact on over 300 Mha. Impact on food security is rated large, with desirable impacts on over 100 million people.

Advantages include**:**

* **Wide suitability:**Grassland is the world’s largest land area, totaling some 3.5 billion hectares. For grassland with limited rainfall, relatively few other climate solutions are available.
* **Improved forage productivity:** Using intensive rotational grazing (IRG) as a case in point, Badgery et al. (2012), find increased internal rate of return with the adoption of a 20-paddock sheep grazing system in Australia for three years. Owensbee et al (2013) studying the use of IRG on steer production in a tall grass prairie ecosystem in the U.S. also reported gains in productivity per hectare, biomass growth, and economic gains for the IRG system in comparison to conventionally managed systems.
* **Relatively low first cost:** when compared to silvopasture, costs to establish managed grazing are very reasonable. Some forms of managed grazing are free to establish.
* **Environmental benefits:** Managed grazing practices can increase biodiversity, restore degraded grasslands, and improve downstream water quality (Toensmeier 2016).
* **Benefits to the farm or ranch:** Managed grazingincreases soil organic matter, improving fertility and water-holding capacity. It is also noted as a climate change adaptation strategy (Toensmeier 2016).

### Similar Solutions

*Silvopasture* incorporates trees on grazing lands. It has higher sequestration rates, higher establishment costs, and is more constrained by rainfall than managed grazing. Compost application on rangeland is emerging as a new practice with impressive sequestration rates (Machmuller 2015).

Other grassland solutions include *grassland protection.* Degraded grasslands can be used for *farmland restoration, afforestation, bamboo, perennial biomass,* and *multistrata agroforestry,* climate permitting.

*Improved livestock feeds* also targets ruminant livestock, but focused on reducing enteric methane by changing diet and introducing feed additives. *Methane biodigesters* and *composting* manage the manure from confined livestock operations to reduce emissions and produce co-benefits.

### Arguments for Adoption

Given that grazing is the world’s largest land use, and a major source of emissions, solutions that improve its life cycle analysis are of great importance. Managed grazing is one of the most cost-effective biosequestration options (IPCC 2014). When compared to silvopasture, it is more widely adapted in terms of rainfall, and has lower startup costs and a shorter period of reduced profitability after establishment. Even strong adoption of diet change and food waste reduction do not eliminate the need for livestock products, thus climate-friendly approaches are necessary.

### Additional Benefits and Burdens

Compared to silvopasture, the only other grazing solution, managed grazing is less expensive to establish, has a shorter period of delayed profit, and has a lower per-hectare sequestration rate.

Table 1.3 Food Production Solutions Comparison: On-Farm Impacts

**Yield Gains:** loss of yield “loss”,no impact “n/a”,1-9% low, 10-24% medium, 25%+ high. **First Cost**: Free is $0**,** Low is $1-100, Medium is $100-500, Expensive is $500+. **Net Profit Margin:** Low is $0-100/ha, Medium is $100-500, High is $500+. **Delayed Profit Period:** Short is 0-2, Mid is 3-6, Long is 6+

|  | **Yield Gains** | **Startup Cost** | **Net Profit** | **Delayed Profit Period** |
| --- | --- | --- | --- | --- |
| Conventional cropping | n/a | n/a | Medium | n/a |
| Conventional grazing | n/a | n/a | Medium | n/a |
| Conservation agriculture | Low | Medium | High | Mid |
| Farmland restoration | High | Medium | Medium | Short |
| Farm water use efficiency | n/a | Expensive | Medium | Short |
| Improved rice | Loss | Free | High | Mid |
| Managed grazing | Medium | Low | High | Mid |
| Multistrata agroforestry | n/a | Expensive | High | Long |
| Nutrient management | n/a | Free | Low | Short |
| Regenerative agriculture | Low | Medium | High | Mid |
| Silvopasture | Medium | Expensive | High | Long |
| System of Rice Intensification | High | Free | High | Mid |
| Tree intercropping | Low | Expensive | Medium | Long |
| Tropical staple tree crops | High | Expensive | High | Long |
| Women smallholders | high | Free | High | Short |

Table 1.4 Food Production Solutions Comparison: On-Farm Impacts Social and Ecological Impacts

**Ecosystem Services** is subjective based on impacts on biodiversity, water quality, etc. **Social Justice Benefits:** Is solution Targeted to disadvantaged producers like smallholders and women, Relevant to them, or Not Applicable (n/a). **Climate Impacts per Hectare:** Low 0-3.7 t CO2-eq/ha/yr (0-1tC),Medium 3.8-11.0 t CO2-eq/yr (1-3 tC), High 11.1+ tCO2-eq/yr (3+tC). **Global Adoption Potential:** Low 0-100Mha, Medium 101-500 Mha, High 500+ Mha

|  | **Ecosystem Services** | **Social Justice Benefits** | **Climate Impact/ha** | **Global Adoption Potential** |
| --- | --- | --- | --- | --- |
| Conventional cropping | n/a | n/a | n/a | n/a |
| Conventional grazing | n/a | n/a | n/a | n/a |
| Conservation agriculture | Low | Relevant | Low | Medium |
| Farmland restoration | Medium | Relevant | Medium | Medium |
| Farm water use efficiency | Low | Relevant | Low | Medium |
| Improved rice | Medium | Relevant | high | Low-medium |
| Managed grazing | Low | Relevant | Low | Medium-high |
| Multistrata agroforestry | High | Relevant | High | Low |
| Nutrient management | Medium | Relevant | Low | High |
| Regenerative agriculture | Medium | Relevant | Low | Medium-high |
| Silvopasture | High | Relevant | High | Low-medium |
| System of Rice Intensification | Medium | Targeted | Medium | Low |
| Tree intercropping | High | Relevant | Medium | Medium |
| Tropical staple tree crops | Medium | Relevant | High | Low-medium |
| Women smallholders | n/a | Targeted | Low | Low |

# Methodology

## Introduction

Project Drawdown’s models are developed in Microsoft Excel using standard templates that allow easier integration with each other since integration is critical to the bottom-up approach used. The template used for this solution was the Land Model which accounts for sequestration of carbon dioxide from the atmosphere into plant biomass and soil, and reduction of emissions for a solution relative to a conventional practice. These practices are assumed to use land of a specific type that may be shared across several solutions. The actual and maximum possible adoptions are therefore defined in terms of land area (million hectares). The adoptions of both conventional and solution were projected for each of several Drawdown scenarios from 2015 to 2060 (from a base year of 2014) and the comparison of these scenarios with a reference (for the 2020-2050 segment[[3]](#footnote-3)) is what constituted the results.

Total potential land for *managed grazing* is 780 million hectares, consisting of non-degraded grassland. [[2]](http://www.drawdown.org/solutions/food/managed-grazing#_edn2) This is somewhat higher than Henderson’s (2015) estimate of grassland area amenable to carbon sequestration via grazing.  Current adoption [[3]](http://www.drawdown.org/solutions/food/managed-grazing#_edn3) of *managed grazing* is estimated at 71.6 million hectares. This figure was generated by using meta-analysis of data from 9 sources.

*Agency Level*

The rancher or pastoralist is selected as the agency level for this solution. Though certainly other agents can, do, and should play an important role in this solution, the decision-maker on the ground is the most critical player in implementation.

## Data Sources

A total of 71 sources were used in the model, including 56 peer-reviewed articles, 2 interviews, 3 government sources, and 10 NGO reports.

The BIOSEQ model utilizes estimates of different land cover types by region provided by the UN’s Global Agroecological Zones (GAEZ) project. However, for grasslands it is unable to distinguish grasslands that may be utilized for livestock grazing and those that are not. Henderson (2015) correct GAEZ grassland area data by reconciling it with UN FAOSTAT data on grazing land area reported by national governments, modifying the estimate to 2577 Mha. We used this as our estimate of total available land for improved grazing management.

## Total Available Land

Drawdown’s agricultural production and land use model approach defines the Total Land Area as the area of land (in million hectares) suitable for adoption a given solution. Data on global land is acquired from Global Agro-Ecological Zones database, developed by the Food and Agriculture Organization of the United Nations (FAO) and the International Institute for Applied Systems Analysis (IIASA). The Drawdown Land-Use Model categorizes and allocates land according to agro-ecological zones based on the following factors: thermal climate, moisture regimes, soil quality, slope, cover type, and degradation status. These characteristics influence the suitability of different practices, and solution adoption scenarios are restricted by one or more of these factors.

Determining the total available land for a solution is a two-part process. The technical potential is based on: current land cover or land use; the suitability of climate, soils, and slopes; and on degraded or non-degraded status. In the second stage, land is allocated using the Drawdown Agro-Ecological Zone model, based on priorities for each class of land. The total land allocated for each solution is capped at the solution’s maximum adoption in the *Optimum* Scenario. Thus, in most cases the total available land is less than the technical potential.

Total available land is calculated at 780 million hectares, and consists of non-degraded grassland with minimal or moderate slopes in humid and semi-arid climates.

## Adoption Scenarios

Two different types of adoption scenarios were developed: a Reference (REF) Case which was considered the baseline, where not much changes in the world, and a set of Project Drawdown Scenarios (PDS) with varying levels of ambitious adoption of the solution. Published results show the comparison of one PDS to the REF, and therefore focus on the change to the world relative to a baseline.

The adoption of managed grazing is projected based on weighted "average, medium, and high" growth rates, calculated based on the available country specific area under managed grazing and the region specific total grazing area (Using Henderson et al 2015 estimates). The conservative adoption scenarios assume adoption through 2050, while some of the aggressive adoption scenarios consider an early peak adoption, 70% adoption by 2030. A total of eight custom adoption scenarios were generated with details given below:

1. ***Custom adoption scenario one***: This scenario builds the future projection based on the medium growth rate, as described above.
2. ***Custom adoption scenario two***: This scenario builds the future projection based on the high growth rate, as described above.
3. ***Custom adoption scenario three***: This is scenario one with the assumption that 70% of the total adoption will be achieved by 2030.
4. ***Custom adoption scenario four.*** This is scenario two with the assumption that 70% of the total adoption will be achieved by 2030.
5. ***Custom adoption scenario five.*** This scenario is based on the historic growth rate of organic and holistic grazing using a linear trend.
6. ***Custom adoption scenario six.*** This scenario is based on the growth rate from Costa Rica’s national commitment.
7. ***Custom adoption scenario seven.*** This scenario is based on the growth rate from Brazil’s national commitment.
8. ***Custom adoption scenario eight.*** This scenario is based on the projected growth rate for Latin America.

### Reference Case / Current Adoption

Current adoption of managed grazing is estimated at 71.6 million hectares. This figure is the mean in Mha of: 1) total reported adoption from the two leading holistic grazing NGOs, 2) the total certified organic grazing land as reported by two leading NGOs, 3) the total of data points from 5 studies representing South America, Canada, USA, Australia, and China, which collectively account for 54% of global grazing land (FAOStat 2019).

### Project Drawdown Scenarios

Three Project Drawdown scenarios (PDS) were developed for each solution, to compare the impact of an increased adoption of the solution to a reference case scenario, being:

#### Plausible Scenario - A conservative approach is adopted for the plausible scenario, and future growth of the solution is estimated based on the “average of all” custom adoption scenarios as listed above.

#### Drawdown Scenario – For the drawdown scenario, an ambitious approach is adopted, and future growth of the solution is estimated based on the “high of all” custom adoption scenarios as listed above.

#### Optimum Scenario – For the optimum scenario, custom adoption scenario that is giving maximum growth based on the above listed eight custom adoption scenraio is considered, which is represented by the “custom scenario 8” where future adoption is projected based on the growth rate of Latin America.

## Inputs

### Climate Inputs

Sequestration rates are set at 0.67, 0.47, 0.64, and 0.67 tons of carbon per hectare per year for tropical humid, temperate/boreal humid, tropical semi-arid, and temperate/boreal semi-arid climates respectively. This is the result of meta-analysis of 97 data points from 51 sources. Note that several higher rates were excluded automatically by the model as outliers. It is assumed that there is no change in methane and nitrous oxide emissions on conversion from conventional to *managed grazing*.

Table . Climate Inputs

|  | **Units** | **Project Drawdown Data Set Range** | **Model Input** | **Data Points (#)** | **Sources (#)** |
| --- | --- | --- | --- | --- | --- |
| Biosequestration tropical humid | *tC/ha/yr* | 0.13-1.99 | 0.67 | 6 | 4 |
| Biosequestration temperate/boreal humid | *tC/ha/yr* | 0.02-0.92 | 0.47 | 28 | 13 |
| Biosequestration tropical semi-arid | *tC/ha/yr* | -0.31-1.58 | 0.64 | 10 | 8 |
| Biosequestration temperate/boreal semi-arod | *tC/ha/yr* | -0.19-1.44 | 0.67 | 53 | 26 |

Note: Project Drawdown data set range is defined by the low and high boundaries which are respectively 1 standard deviation below and above the mean of the collected data points[[4]](#footnote-4).

*Modeling Saturation*

Biosequestration does not have limitless potential. In most cases, there is a maximum amount of carbon that can be stored in soils and aboveground perennial biomass before they become saturated. Biosequestration continues after saturation but is offset by more or less equal emissions. In most cases soils, and biomass can return to their approximate pre-agricultural or pre-degradation levels of carbon. This takes anywhere between 10-50 years in agricultural cases, and sometimes somewhat longer in the case of ecosystems like forests. Data about saturation time is very limited.

The Drawdown land model takes the conservative approach that all land units currently adopted for agricultural solutions (including multistrata agroforestry) have already achieved saturation, and will not be contributing additional sequestration. New adopted land is assumed to sequester for at least 30 years before achieving saturation.

Note that there are some important exceptions to saturation. Certain ecosystems continue to sequester soil carbon for centuries, notably peatlands and coastal wetlands. Some scientists argue that tropical forests can continue to sequester carbon at a slower rate after saturation. The addition of biochar to saturated soils may be able to overcome this constraint, as does the use of biomass from bamboo or afforestation in long-term products like buildings.

### Financial Inputs

First costs are estimated at US$75.01 per hectare. [[5]](http://www.drawdown.org/solutions/food/silvopasture#_edn5) For all agricultural solutions, it is assumed that there is no conventional first cost, as conventional grazing (in this case) is already in place on the land. Results are based on meta-analysis of 15 data points from 14 sources.

Net profit per hectare is US$279.67 per year (19 data points from 12 sources), compared to US$154.12 per year for the conventional practice (20 data points from 16 sources).

Operating cost is calculated at US$1,672.13 per hectare (4 data points from 2 sources), compared with $328.41 per hectare for conventional grazing (9 data points from 8 sources).

Table . Financial Inputs for Conventional Technologies

|  | **Units** | **Project Drawdown Data Set Range** | **Model Input** | **Data Points (#)** | **Sources (#)** |
| --- | --- | --- | --- | --- | --- |
| First costs (Conventional) | *US$2014/ha* | $0 | $0 | n/a | n/a |
| Net profit (Conventional) | *US$2014/ha* | $69.49-$323.38 | $154.12 | 18 | 16 |
| Operating Cost (Conventional) | *US$2014/ha* | $28.06-$684.58 | $328.42 | 9 | 8 |

Table . Financial Inputs for Solution

|  | **Units** | **Project Drawdown Data Set Range** | **Model Input** | **Data Points (#)** | **Sources (#)** |
| --- | --- | --- | --- | --- | --- |
| First costs (Solution) | *US$2014/ha* | $5.66-$155.01 | $75.01 | 15 | 14 |
| Net profit (Solution) | *US$2014/ha* | $18.69-$540.66 | $279.67 | 19 | 12 |
| Operating Cost (Solution) | *US$2014/ha* | $802.14-$2,542.12 | $1,672.13 | 4 | 2 |

Farmers and ranchers transitioning to carbon-friendly practices face a period of reduced income. This reflects an individual learning curve, customization of the system to their farm or ranch, and time for the practice to begin to have in impact on productivity. Meta-analysis of 10 data points from 4 sources shows that in the case of implementation of agroforestry solutions, net profits per hectare do not exceed business-as-usual for 3.5 years. To account for this delay in profitability, the Drawdown model assumes that net profit per hectare is 25% of the conventional rate until 4 years have elapsed.

### Other Inputs

Yield gains compared to business-as-usual annual grazing were set at 21.4 percent, based on meta-analysis of 14 data points from 11 sources.

## Assumptions

Six overarching assumptions have been made for Project Drawdown models to enable the development and integration of individual model solutions. These are that infrastructure required for solution is available and in-place, policies required are already in-place, no carbon price is modeled, all costs accrue at the level of agency modeled, improvements in technology are not modeled, and that first costs may change according to learning. Full details of core assumptions and methodology will be available at [www.drawdown.org](http://www.drawdown.org). Beyond these core assumptions, there are other important assumptions made for the modeling of this specific solution. These are detailed below.

Beyond these core assumptions, there are other important assumptions made for the modeling of this specific solution. These are detailed below.

1. This study does not account for soil carbon saturation. Typically sequestration continues for 10-50 years and then ceases. As our window is 2020-2050, we are assuming that saturation will not be a major factor until after 2050.
2. We are assuming that emissions from managed grazing are equivalent to those from baseline grazing practices. In the absence of strong evidence in any direction, this is the conservative modeling choice.
3. Henderson (2015) calculates that the majority of grazing land is not amenable to sequestration via managed grazing. However, Lal (2018) and others do not make this assumption. This study assumes that all lands are amenable but limits the total area for the solution to close to Henderson’s estimate.
4. This study assigns this solution to non-degraded grassland; however some authors have suggested that carbon sequestration is actually only viable on lands which have lost their historic carbon; thus degraded land may be better suited to sequestration from managed grazing.

## Integration

The complete Project Drawdown integration documentation (will be available at [www.drawdown.org](http://www.drawdown.org)) details how all solution models in each sector are integrated, and how sectors are integrated to form a complete system. Those general notes are excluded from this document but should be referenced for a complete understanding of the integration process. Only key elements of the integration process that are needed to understand how this solution fits into the entire system are described here.

*Managed grazing* is part of Drawdown’s Food sector, specifically the supply-side set that incorporate food production. Within agriculture it is part of a cluster of solutions based on livestock production.

***The Agroecological Zone model***

Drawdown’s approach seeks to model integration between and within sectors, and avoid double counting. Several tools were developed to assist in this effort. The Agroecological Zone (AEZ) model categorizes the world’s land by: current cover (e.g. forest, grassland, cropland), thermal climate, moisture regime, soil quality, slope, and state of degradation.  Both Food (supply-side) and Land Use solutions were assigned to AEZs based on suitability. Once current solution adoption was allocated for each zone (e.g. semi-arid cropland of minimal slopes), zone priorities were generated and available land was allocated for new adoption. Priorities were determined based on an evaluation of suitability, consideration of social and ecological co-benefits, mitigation impact, yield impact, etc. For example, *Indigenous peoples’ land management* is given a higher priority than *forest protection* for AEZs with forest cover, in recognition of indigenous peoples’ rights and livelihoods. *Multistrata agroforestry* is highly prioritized in tropical humid climates due to its high sequestration rate, food production, and highly limited climate constraints.

Each unit of land was allocated to a separate solution to avoid overlap between practices. The exception to this are *farmland irrigation*, *nutrient management*, and *women smallholders*, which can be implemented in addition to other practices. The constraint of limited available land meant that many solutions could not reach their technical adoption potential. The AEZ model thus prevents double-counting for adoption of agricultural and land use solutions.

Drawdown’s agricultural production and land use model approach defines the Total Land Area as the area of land (in million hectares) suitable for adoption a given solution. Data on global land is acquired from Global Agro-Ecological Zones database, developed by the Food and Agriculture Organization of the United Nations (FAO) and the International Institute for Applied Systems Analysis (IIASA). The Drawdown Land-Use Model categorizes and allocates land according to agro-ecological zones based on the following factors: thermal climate, moisture regimes, soil quality, slope, cover type, and degradation status. These characteristics influence the suitability of different practices, and solution adoption scenarios are restricted by one or more of these factors.

Determining the total available land for a solution is a two-part process. The technical potential is based on: current land cover or land use; the suitability of climate, soils, and slopes; and on degraded or non-degraded status. In the second stage, land is allocated using the Drawdown Agro-Ecological Zone model, based on priorities for each class of land. The total land allocated for each solution is capped at the solution’s maximum adoption in the *Optimum* Scenario. Thus, in most cases the total available land is less than the technical potential.

Drawdown’s Agro-Ecological Zone model allocates current and projected adoption of solutions to the planet’s forest, grassland, rainfed cropland, and irrigated cropland areas. Adoption of *managed grazing* was limited to non-degraded grassland, and was the second-highest priority there after *silvopasture*.

***The Yield model***

Drawdown’s yield model calculates total annual global supply of crops and livestock products based on their area of adoption in each of the three scenarios, and global yield impacts of each solution (including both gains due to increased productivity per hectare and losses due to reduction of productive area due to adoption of non-agricultural solutions, e.g., loss of grazing area due to afforestation of grasslands). Grain surpluses in the yield model were also used to set a ceiling for the amount of crops available for use as feedstock for the *bioplastic* Materials solution.

The yield model matches demand and supply as an integrated system. Both *Reference* Scenarios showed a food deficit in the high and medium population scenarios (see *family planning*and *educating girls* solutions). This would require the clearing of forest and grassland for food production, with associated emissions from land conversion.

All three Drawdown scenarios show agricultural production sufficient to meet food demand and provide a surplus that can be used in bio-based industry, for example as feedstock for *bioplastic*production*.*Due to this surplus, no land clearing is necessary, resulting in impressive emissions reduction from avoided deforestation.  Because population change (resulting from *educating girls*and *family planning*),*plant-rich diet*, and *reduced food waste* are the principal drivers of this effect, Drawdown allocates the resulting reduction in emissions from land clearing to these solutions. However, as the impacts of population on yield and food demand are highly complex, we do not include avoided land conversion emissions associated with population change in the final emissions calculations for those solutions.

## Limitations/Further Development

***Limited data on adoption*.** No reports or experts were able to provide a global estimate of the current extent of this practice. Data on growth rates and adoption commitments are also limited.

***Inconsistent depth of soil carbon measurements*.** The studies measure soil organic carbon at varying depths ranging from 2 to 100 cm and thus should be taken with a grain of salt in their consistency. The largest review (Conant et al. 2001) from which studies were sourced measured to a depth of 22 cm on average, yet the review notes that factors controlling SOC turnover in deep soils (> 50 cm) are increasingly recognized as significant to the overall SOC storage and stability (Fontaine et al., 2007, Rumpel and Kögel-Knabner, 2010). Carbon stabilized at depths > 20 cm accounts for over 50% of the total organic C stocks in several ecosystem types (Jobbagy and Jackson, 2000), and deep SOC is often considered recalcitrant or inaccessible to microbial degradation (Rumpel and Kögel-Knabner, 2010).  While soils may have differing amounts of carbon and nitrogen in the surface 30 cm on grazed pastures as opposed to native rangeland where livestock are excluded, they may be the same below 30 cm across grazing treatments (Manley et al. 1995).

***Short time spans of observation of intervention*.** Many of the time frames of studies used to derive carbon sequestration rates for our model are very short, potentially muting different longer-term effects. This could underestimate the carbon sequestration rates attributable to improved grazing management for cases that require longer time horizons to improve rangeland health and productivity (Teague et al. 2011), or overestimate carbon sequestration rates in cases where soils are close to their carbon saturation point and cannot sustain short-term sequestration rates into the long run. It typically takes 2-3 years after consistent management changes for a grazing system to adapt to the new conditions (Provenza, 2003, 2008; Pinchak et al. 2010; Teague et al. 2013). The trials in many grazing studies cited in Briske et al. (2008) are no more than 4 years in length, despite the fact that grazing experiments less than five years length in mesic or 10 years long in drier rangelands does not capture the inherent climate and spatial variability of rangelands (Burke et al. 1998; Teague et al. 2013).

***Geographical bias*.** The rates obtained for the projections draw predominantly from studies conducted in Western countries. Moreover, the great majority of data is from temperate/boreal semi-arid climates, with little data available from the rest of the world.

***May not represent potential based on state-of-the-art practices*.** In many cases, the evolving experience base and inconsistent terminology has led to different techniques being researched from those actually being adopted by graziers – thus differences between much of the literature and the commercial results (McCosker 2000). Techniques being used by innovative graziers often changing over the years with more knowledge and experience. In addition, much of the research on grazing systems has been done on smaller physical scale and shorter timescales than the realities on which actual adaptive grazing management strategies have been developed. The literature suffers from a disconnect between research and actual management knowledge base (Roche et al. 2015). The soil carbon sequestration rates documented by peer-reviewed sources used in our model therefore may not represent the full potential of what is achievable through managed grazing.

***Potential for confounded relationships.*** Grazing effects can also be confounded by the interaction between grazing intensity and cultivation history (Fuhlendorf et al. 2002). Soil carbon, total nitrogen, organic matter, NO3-N, and K were all significantly higher on sites that had not been cultivated than on sites that had been cultivated and restored. The studies used in the model represent a broad set of observations that do not control for underlying cultivation history among other key variables such as dominant grass composition, climate, and degree of saturation.

***Difficulty of controlling for variation*** in improved grazing management practices. It is difficult to disaggregate the many practices lumped under “managed grazing”. Also, research experiments in grazing studies reportedly “almost never” manage rangeland adaptively using general best practices when testing the impacts of rotational grazing, such that differences between the baseline continuous and rotational grazing cases may often be understated (Teague et al. 2013). To the extent that grazing experiments do not reflect adaptive management changes, they do not represent “operational scale soil-plant-animal interactions and the resulting effects of defoliation” and risk being “merely unique inflections in time and space of biophysical processes that link soils, plants, herbivores, and people not generalizations that can be extrapolated across management systems and landscapes” (Teague et al. 2013).

***Small size of paddocks*.** Paddocks in grazing trials are less than 25 hectares and often under 5 hectares, which is smaller than the size of paddocks on many commercial ranches (Teague et al. 2013). Smaller experimental paddocks tend to reduce internal forage heterogeneity and hence produce more uniform distribution of grazing pressure, misrepresenting the way that grazing animals at low-stock densities use larger landscapes characteristic of continuous stocking (Barnes et al. 2008; Teague et al. 2013). These small-sized paddocks may serve well in representing smallholder grazing, however.

***Gaps in tracking what is attributable to grazing treatment vs. soil/topographic features vs. weather and climactic variability.*** The same practice often will have inconsistent results between regions and sites. Our model is limited in its ability to disaggregate rates by biophysical characteristics; more detailed modeling could be done in the future. Some grazing trials do not account for differences in soils between treatments, despite high edaphic and topographic variability (Teague et al. 2013). Past analysis (Teague & Foy 2004) of a study on three grazing management treatments (Heitschmidt et al. 1985, 1990) found that a simulation model was able to generate key parameters to provide evidence that differences attributed to grazing treatment were likely due to differences in soil and slope characteristics instead of grazing treatments. It is also hard to gauge treatment differences in rangeland ecosystems due to slow and erratic response times triggered by reactions to stochastic events such as weather and climactic variability that interact with management actions (Walker 1988; Danckwerts et al. 1993; Watson et al. 1996; Teague at al. 2004, 2010a, 2013).

***Limited******ability to account for longer-term effects of climate change*.** Severe drought and heavy grazing can lead to major losses of SOC. Fluctuations in climactic factors such as drought can induce loses of carbon in rangeland ecosystems, and change rangelands from sinks to sources of CO2 because limiting soil water proportionally affects photosynthetic rates more than total respiration.[[5]](#footnote-5) One more reason to be conservative in the numbers we choose in order to provide a bit of a buffer for any potential losses triggered by climate change. It would be great if any future refinements of the model could better take into account management and environment interactions sensitive to climate—as well as soil and initial C conditions.

# Results

## Adoption

Below are shown the world adoptions of the solution in some key years of analysis in functional units and percent for the three Project Drawdown scenarios.

Total adoption in the *Plausible* Scenario is 421.52 million hectares in 2050, representing 54.03 percent of the total suitable land. Of this, 349.89 million hectares are adopted from 2020-2050.

Total adoption in the *Drawdown* Scenario is 757.28 million hectares in 2050, representing 97.08 percent of the total suitable land. Of this, 685.65 million hectares are adopted from 2020-2050.

Total adoption in the *Optimum* Scenario is 780.50 million hectares in 2050, representing 100.00 percent of the total suitable land. Of this, 708.14 million hectares are adopted from 2020-2050.

Table . World Adoption of the Solution

| **Solution** | **Units** | **Base Year (2014)** | **New Adoption by 2050** | | |
| --- | --- | --- | --- | --- | --- |
| **Plausible** | **Drawdown** | **Optimum** |
| Managed Grazing | Mha | 71.6 | 349.89 | 685.65 | 708.14 |
| % Total Land Available | 9.17% | 54.03% | 97.08% | 100.00% |

Figure 3.1: World annual adoption 2020-2050 (Mha)

## Climate Impacts

Below are the emissions results of the analysis for each scenario which include total emissions reduction, atmospheric concentration changes, and sequestration where relevant. For a detailed explanation of each result, please see the glossary (Section 6).

Biosequestration impact is 14.85, 32.10, and 34.57 gigatons of carbon-dioxide equivalent in the *Plausible, Drawdown,* and *Optimum* Scenarios respectively.

Table . Climate Impacts

| **Scenario** | **Maximum Annual Emissions Reduction** | **Total Emissions Reduction** | **Max Annual CO2 Sequestered** | **Total Additional CO2 Sequestered** | **Total Atmospheric CO2-eq Reduction** | **Emissions Reduction in 2030** | **Emissions Reduction in 2050** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *(Gt CO2-eq/yr.)* | *Gt CO2-eq/yr. (2020-2050)* | *(Gt CO2-eq/yr.)* | *Gt CO2-eq/yr. (2020-2050)* | Gt CO2-eq (2020-2050) | (Gt CO2-eq/year) | *(Gt CO2-eq/year)* |
| ***Plausible*** | 0.00 | 0.00 | 0.74 | 14.85 | 14.85 | 0.40 | 0.74 |
| ***Drawdown*** | 0.00 | 0.00 | 1.45 | 32.10 | 32.10 | 0.89 | 1.45 |
| ***Optimum*** | 0.00 | 0.00 | 1.50 | 34.57 | 34.57 | 0.95 | 1.50 |

The solution was integrated with all other Project Drawdown solutions and may have different emissions results from the models. This is due to adjustments caused by interactions among solutions that limit full adoption (such as by feedstock or demand limits) or that limit the full benefit of some solutions (such as reduced individual solution impact when technologies are combined).

Table . Impacts on Atmospheric Concentrations of CO2-eq

| **Scenario** | **GHG Concentration Change in 2050** | **GHG Concentration Rate of Change in 2050** |
| --- | --- | --- |
| *PPM CO2-eq (2050)* | *PPM CO2-eq change from 2049-2050* |
| **Plausible** | 1.26 | 0.05 |
| **Drawdown** | 2.70 | 0.10 |
| **Optimum** | 2.90 | 0.10 |

Figure . World AnnualGreenhouse Gas Emissions Reduction

## Financial Impacts

Below are the financial results of the analysis for each scenario. For a detailed explanation of each result, please see the glossary.

Note that the financial results have changed from those published in the first edition of the *Drawdown* book.

For the *Plausible* Scenario, cumulative first cost is US$30.69 billion. Marginal first cost is the same as cumulative first cost. Net operating savings is US$-9,4717.74 billion. Net profit margin is US$639.15 billion, and lifetime profit margin is US$1,291.90. Lifetime cashflow savings NPV is $-1,567.62.

For the *Drawdown* Scenario, cumulative first cost is US$61.28 billion. Marginal first cost is the same as cumulative first cost. Net operating savings is US$-20,348.13 billion. Net profit margin is US$1,431.39 billion, and lifetime profit margin is US$2,600.89 billion. Lifetime cashflow savings NPV is $-3,424.67 billion.

For the *Optimum* Scenario, cumulative first cost is US$63.65 billion. Marginal first cost is the same as cumulative first cost. Net operating savings is US$-21,914.21 billion. Net profit margin is US$1,558.91 billion, and lifetime profit margin is US$2,707.22 billion. Lifetime cashflow savings NPV is $-3,669.27 billion.

Table . Financial Impacts

| **Scenario** | **Cumulative First Cost** | **Marginal First Cost** | **Net Operating Savings** | **Net Profit Margin** | **Lifetime Profit Margin** | **Lifetime Cashflow Savings NPV (of All Implementation Units)** |
| --- | --- | --- | --- | --- | --- | --- |
| *2015-2050 Billion USD* | *2015-2050 Billion USD* | *2020-2050 Billion USD* | *2020-2050 Billion USD* | *2020-2050 Billion USD* | *Billion USD* |
| **Plausible** | *$30.69* | *$30.69* | *$-9,417.74* | *$639.15* | *$1,291.90* | *$-1,567.62* |
| **Drawdown** | *$61.28* | *$61.28* | *$-20,348.13* | *$1,431.39* | *$2,600.89* | *$-3,424.67* |
| **Optimum** | *$63.65* | *$63.65* | *$-21,914.21* | *$1,558.91* | *$2,707.22* | *$-3,669.27* |

Figure 3.3 Net Profit Margin Solution vs. conventional practice

## Other Impacts

Yield increases in MMT 2020-2050: 3.87, 8.37, and 9.01 in the three scenarios respectively.

# Discussion

Grazing is the world’s largest land use. Global consumption of livestock products is on the rise. Emissions from grazed livestock are a major contribution to climate change. *Managed grazing* is a solution that helps to address these challenges. It represents in many cases a net-sequestration system for producing ruminant livestock products for the period until soil carbon saturation occurs. Even the most aggressive *plant-based diet* scenarios show significant need for livestock products in 2050. Thus, *managed grazing* is an essential supply-side food solution in any mitigation program.

For a solution that has received so much press, there are huge gaps. Few other solutions show this much controversy. While the results presented in this study are more modest than some of the claims made for this solution, the results show that this is indeed an important solution.

Silvopasture (the subject of a separate Drawdown solution) has far greater potential impact due to a higher sequestration rate, but is limited to grasslands humid enough to support tree growth. This leaves the majority of the world’s grasslands in need of a solution, and managed grazing is such a strategy, indeed one of few solutions available for these vast areas of grazing land.

## Limitations

The sequestration data used in this study is fairly strong and in line with projection of most other authors. However, the data on current and projected adoption, productivity, and financials are weak and point to a need for further research.

A key limitation was the lack of information on current adoption. More robust adoption data would improve the model results. Financial data is also rarely reported and is largely limited to Organization for Economic Cooperation and Development (OECD) countries. Financial results would benefit from robust data from other regions. Yield gain data is also very limited in this study.

There remains the important question raised by some authors of whether all grazing lands are even amenable to net sequestration from managed grazing. It also remains a subject of disagreement among researchers whether the (very desirable) higher sequestration rates proposed by more intensive forms of managed grazing (e.g. AMP) are valid.

It may be that AMP grazing is a distinct enough practice (in terms of sequestration rates, financials, yield gains etc) that it is worthy of modeling on its own as a distinct practice. Indeed, the few data points that were available for this practice were excluded as outliers by the Drawdown model. For now, insufficient data is available for undertaking this step.

The Drawdown AEZ model currently assigns this solution to non-degraded grassland. However many researchers point out that sequestration potential from *managed grazing* is highest on degraded grasslands, as they have lost the most soil carbon and thus have the most room for improvement before reaching saturation.

## Benchmarks

Benchmarks for *managed grazing* vary widely depending on assumptions about available land and sequestration rates. Smith (2007) estimates an annual impact of 0.1-0.8 Gt CO2-eq/yr in 2030. Griscom (2017) takes conservative assumptions with an extremely low sequestration rate and use of Henderson (2015)’s calculations about the area amenable to sequestration. The study assumes a maximum of 712 Mha available, and a sequestration rate of 0.06 t/ha/yr, with 100 years until saturation. Lal (2018) calculates the technical biosequestration potential. It estimates maximum adoption on 2,725 Mha, assuming a sequestration rate of 0.15-0.30 t/ha/yr and 30 to 50 years until saturation. The paper calculates the annual impact at 1.51-3.01 Gt CO2-eq/yr and the cumulative impact as 60.3-120.6 Gt CO2-eq for the period 2020-2100. IPCC (2019) ranks managed grazing as having a “moderate” climate impact, at category for which the range is 0.3-3.0 Gt CO2-eq/yr in 2030. The Drawdown model’s calculations are thus in line with the three most recent benchmarks.

Table . Benchmarks

| **Source and Scenario** | **New Adoption Mha** | **Mitigation Impact**  **Gt CO2-eq in 2030** |
| --- | --- | --- |
| Smith (2007) | unreported | 0.1-0.8 |
| Griscom (2017) | Up to 712 | 0.15-0.70 |
| Lal (2018) | 2,725 (technical potential) | 1.51-3.01 |
| IPCC (2019) | 500-3,000 | 0.3-3.0 |
| *Plausible* Scenario | 349.89 | 0.40 |
| *Drawdown* Scenario | 685.65 | 1.45 |
| *Optimum* Scenario | 708.14 | 1.50 |

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# Glossary

**Adoption Scenario** – the predicted annual adoption over the period 2015 to 2060, which is usually measured in **Functional Units**. A range of scenarios is programmed in the model, but the user may enter her own. Note that the assumption behind most scenarios is one of growth. If for instance a solution is one of reduced heating energy usage due to better insulation, then the solution adoption is translated into an increase in use of insulation. There are two types of adoption scenarios in use: **Reference (REF)** where global adoption remains mostly constant, and **Project Drawdown Scenarios (PDS)** which illustrate high growth of the solution.

**Approximate PPM Equivalent** – the reduction in atmospheric concentration of CO2 (in **PPM**) that is expected to result if the **PDS Scenario** occurs. This assumes a discrete avoided pulse model based on the Bern Carbon Cycle model.

**Average Abatement Cost** – the ratio of the present value of the solution (**Net** **Operating Savings** minus **Marginal First Costs**) and the **Total Emissions Reduction**. This is a single value for each solution for each **PDS Scenario**, and is used to build the characteristic “*Marginal Abatement Cost*” curves when Average Abatement Cost values for each solution are ordered and graphed.

**Average Annual Use** – the average number of functional units that a single implementation unit typically provides in one year. This is usually a weighted average for all users according to the data available. For instance, total number of passenger-km driven by a hybrid vehicle in a year depends on country and typical number of occupants. We take global weighted averages for this input. This is used to estimate the **Replacement Time**.

**Cumulative First Cost** – the total **First Cost** of solution **Implementation Units** purchased in the **PDS Scenario** in the analysis period. The number of solution implementation units that are available to provide emissions reduction during the analysis period is dependent on the units installed prior to the analysis period, and hence all implementation units installed after the base year are included in the cumulative first costing (that is 2015-2050).

**Direct Emissions** – emissions caused by the operation of the solution, which are typically caused over the lifetime of the solution. They should be entered into the model normalized per functional unit.

**Discount Rate**- the interest rate used in discounted cash flow (DCF) analysis to determine the present value of future cash flows. The discount rate in DCF analysis takes into account not just the time value of money, but also the risk or uncertainty of future cash flows; the greater the uncertainty of future cash flows, the higher the discount rate. Most importantly, the greater the discount rate, the more the future savings are devalued (which impacts the financial but not the climate impacts of the solution).

**Emissions** **Factor**– the average normalized emissions resulting from consumption of a unit of electricity across the global grid. Typical units are kg CO2e/kWh.

**First Cost**- the investment cost per **Implementation Unit** which is essentially the full cost of establishing or implementing the solution. This value, measured in 2014$US, is only accurate to the extent that the cost-based analysis is accurate. The financial model assumes that the first cost is made entirely in the first year of establishment and none thereafter (that is, no amortization is included). Thus, both the first cost and operating cost are factored in the financial model for the first year of implementation, all years thereafter simply reflect the operating cost until replacement of the solution at its end of life.

**Functional Unit** – a measurement unit that represents the value, provided to the world, of the function that the solution performs. This depends on the solution. Therefore, LED Lighting provides petalumen-hours of light, Biomass provides tera-watt-hours of electricity and high speed rail provides billions of passenger-km of mobility.

**Grid Emissions** – emissions caused by use of the electricity grid in supplying power to any operation associated with a solution. They should be in the units described below each variable entry cell. Drawdown models assume that the global electric grid, even in a Reference Scenario, is slowly getting cleaner, and that emissions factors fall over time resulting in lower grid emissions for the same electricity demand.

**Implementation Unit** – a measurement unit that represents how the solution practice or technology will be installed/setup and priced. The implementation unit depends on the solution. For instance, implementing electric vehicles (EV) is measured according to the number of actual EV’s in use, and adoption of Onshore Wind power is measured according to the total terawatts (TW) of capacity installed worldwide.

**Indirect Emissions** – emissions caused by the production or delivery or setup or establishment of the solution in a specified area. These are NOT caused by day to day operations or growth over time, but they should be entered into the model normalized on a per functional unit or per implementation unit basis.

**Learning Rate/Learning Curve** - Learning curves (sometimes called experience curves) are used to analyze a well-known and easily observed phenomenon: humans become increasingly efficient with experience. The first time a product is manufactured, or a service provided, costs are high, work is inefficient, quality is marginal, and time is wasted. As experienced is acquired, costs decline, efficiency and quality improve, and waste is reduced. The model has a tool for calculating how costs change due to learning. A 2% learning rate means that the cost of producing a *good* drops by 2% every time total production doubles.

**Lifetime Capacity** – this is the total average functional units that one implementation unit of the solution or conventional technology or practice can provide before replacement is needed. All technologies have an average lifetime usage potential, even considering regular maintenance. This is used to estimate the **Replacement Time**. and has a direct impact on the cost to install/acquire technologies/practices over time. E.g. solar panels generate, on average, a limited amount of electricity (in TWh) per installed capacity (in TW) before a new solar panel must be purchased. Electric vehicles can travel a limited number of passenger kilometers over its lifetime before needing to be replaced.

**Lifetime Operating Savings**–the operating cost in the PDS versus the REF scenarios over the lifetime of the implementation units purchased during the model period regardless of when their useful life ends.

**Lifetime Cashflow NPV**-the present value (PV) of the net cash flows (PDS versus REF) in each year of the model period (2015-2060). The net cash flows include net operating costs and first costs. There are two results in the model: Lifetime Cashflow NPV for a Single **Implementation Unit**, which refers to the installation of one **Implementation Unit**, and Lifetime Cashflow NPV of All Units, which refers to all **Implementation Units** installed in a particular scenario. These calculations are also available using profit inputs instead of operating costs.

**Marginal First Cost** – the difference between the **First Cost** of all units (solution and conventional) installed in the **PDS Scenario** and the **First Cost** of all units installed in the **REF Scenario** during the analysis period. No discounting is performed. The number of solution implementation units that are available to provide emissions reduction during the analysis period is dependent on the units installed prior to the analysis period, and hence all implementation units installed after the base year are included in the cumulative first costing (that is 2015-2050).

**Net Annual Functional Units (NAFU)** – the adoption in the PDS minus the adoption in the REF in each year of analysis. In the model, this represents the additional annual functional demand captured either by the solution in the **PDS Scenario** or the conventional in the **REF Scenario**.

**Net Annual Implementation Units (NAIU)** – the number of **Implementation Units** of the solution that are needed in the PDS to supply the **Net Annual Functional Units (NAFU).** This equals the adoption in the PDS minus the adoption in the REF in each year of analysis divided by the average annual use.

**Net Operating Savings** – The undiscounted difference between the operating cost of all units (solution and conventional) in the **PDS Scenario** minus that of all units in the **REF Scenario**.

**Operating Costs** – the average cost to ensure operation of an activity (conventional or solution) which is measured in 2014$US/**Functional Unit**. This is needed to estimate how much it would cost to achieve the adoption projected when compared to the **REF Case**. Note that this excludes **First Costs** for implementing the solution.

**Payback Period** – the number of years required to pay all the **First Costs** of the solution using **Net Operating Savings**. There are four specific metrics each with one of **Marginal First Costs** or **First Costs** of the solution only combined with either discounted or non-discounted values. All four are in the model. Additionally, the four outputs are calculated using the increased profit estimation instead of **Net Operating Savings**.

**PDS/ Project Drawdown Scenario** – this is the high growth scenario for adoption of the solution

**PPB/ Parts per Billion** – a measure of concentration for atmospheric gases. 10 million PPB = 1%.

**PPM/ Parts per Million** – a measure of concentration for atmospheric gases. 10 thousand PPM = 1%.

**REF/ Reference Scenario** – this is the low growth scenario for adoption of the solution against which all **PDS scenarios** are compared.

**Regrets solution** has a positive impact on overall carbon emissions being therefore considered in some scenarios; however, the social and environmental costs could be harmful and high.

**Replacement Time**- the length of time in years, from installation/acquisition/setup of the solution through usage until a new installation/acquisition/setup is required to replace the earlier one. This is calculated as the ratio of **Lifetime Capacity** and the **Average Annual Use**.

**TAM/ Total Addressable Market** – represents the total potential market of functional demand provided by the technologies and practices under investigation, adjusting for estimated economic and population growth. For this solutions sector, it represents world and regional total addressable markets for electricity generation technologies in which the solutions are considered.

**Total Emissions Reduction** – the sum of grid, fuel, indirect, and other direct emissions reductions over the analysis period. The emissions reduction of each of these is the difference between the emissions that would have resulted in the **REF Scenario** (from both solution and conventional) and the emissions that would result in the **PDS Scenario**. These may also be considered as “emissions avoided” as they may have occurred in the REF Scenario, but not in the PDS Scenario.

**Transition solutions** are considered till better technologies and less impactful are more cost effective and mature.

**TWh/ Terawatt-hour** – A unit of energy equal to 1 billion kilowatt-hours

1. Kim, Gillespie, and Paudel, “Rotational Grazing Adoption in Cattle Production under a Cost-Share Agreement.” [↑](#footnote-ref-1)
2. Jensen et al., “CATTLE PRODUCERS’ WILLINGNESS TO ADOPT OR EXPAND PRESCRIBED GRAZING IN THE UNITED STATES.” [↑](#footnote-ref-2)
3. For most results, only the differences between scenarios, summed over 2020-2050 were presented, but for the net first cost, the position was taken that to achieve the adoptions in 2020, growth must first happen from 2015 to 2020, and that growth comes at a cost which should be accounted for, hence net first cost results represent the period 2015-2050. [↑](#footnote-ref-3)
4. In some cases, the low boundary is negative for a variable that can only be positive, and in these cases the lowest collected data point is used as the “low” boundary. [↑](#footnote-ref-4)
5. Derner and Schuman 2007. [↑](#footnote-ref-5)