



USV 1842



Funded by the
European Union



DIRECT IMPACT OF CLIMATE CHANGE ON LIVESTOCK PRODUCTION

HEAT STRESS, FEED INTAKE, PRODUCTION,
REPRODUCTION, HEALTH AND MORTALITY

Dr. Dušica Ostojić Andrić



Funded by the
European Union



Introduction

- ❑ Livestock products play an important role in human nutrition and the world's agricultural sector.
- ❑ About 26% of ice-free land is used for cattle breeding, while a third of arable land is used for fodder production.
- ❑ Animal husbandry generates 40 % of the world's agricultural gross domestic product and provides livelihoods for a large part of the world's population.
- ❑ Along with the growth of the world population, the need for livestock products also increases.



introduction

□ Today, animal husbandry is facing increasing pressure from the effects of climate change, such as:

- increase in temperature,
- more variable precipitation patterns,
- more frequent extreme events i
- increase in carbon dioxide concentration.





Introduction



- By 2081–2100, if warming is not limited to 1.5–2°C, one-third of the world's crop and livestock production may be displaced outside of stable climate conditions.
- Direct impacts** of climate change include livestock thermoregulation, metabolism, immune function and production.
- Indirect influences** Climate change impacts include the impact on livestock feed production, water availability, and pest and pathogen populations.

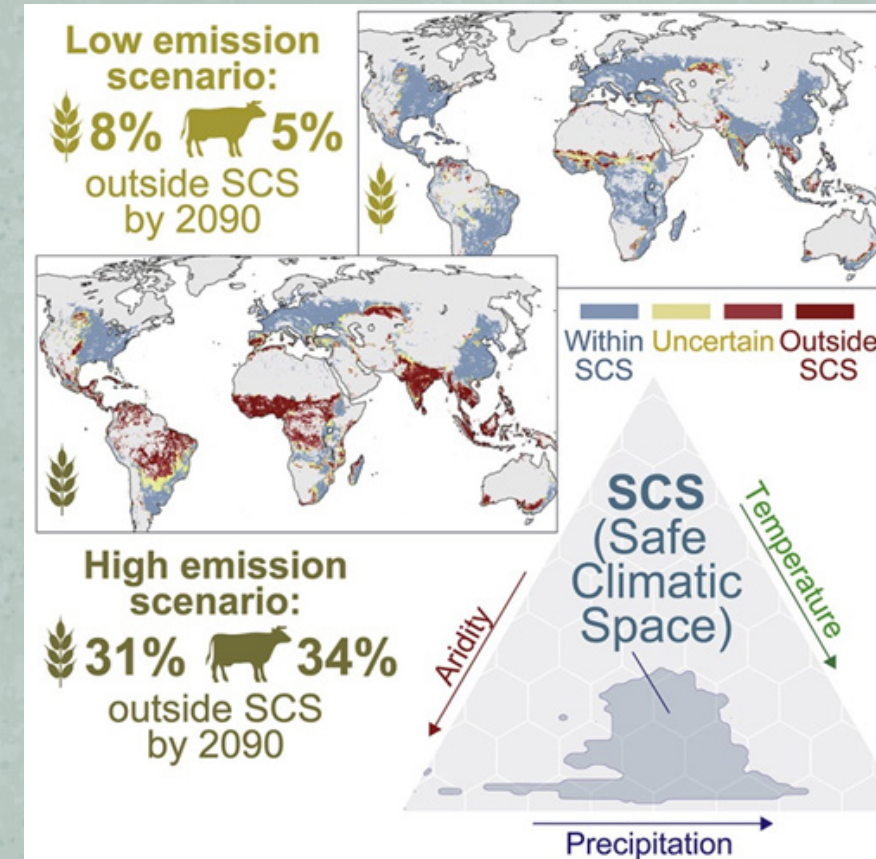


Figure 1. Scenario of high i
low emissions
harmful gases and their
impact on livestock production [1].



Funded by the
European Union



Heat stress

- The production performance of animals depends to a large extent on the ambient conditions in which they are raised.
- The optimal relationship between temperature, humidity and air flow is called **the thermal comfort zone** and is specific to the type of animal.
- In this zone, the animal achieves optimal performance with minimal energy expenditure.
- When the temperature rises outside this zone, **thermal stress occurs**, **and** the animal's organism consumes additional energy to regulate body temperature, which negatively affects productivity.
- If the animal provides an adequate, phenotypic response to the effect of the thermal stressor, we say that it has adapted, ie. **acclimatized**.

Heat stress

- Heat stress caused by high temperature is a bigger problem than stress caused by low temperature.
- It occurs when animals are unable to emit enough heat to maintain **homeothermy**.
- Due to hyperthermia, tachypnea and tachycardia occur.
- The **consequences** on production are: reduced food intake, declining production and reproductive performance, immunodeficiency and increased mortality.

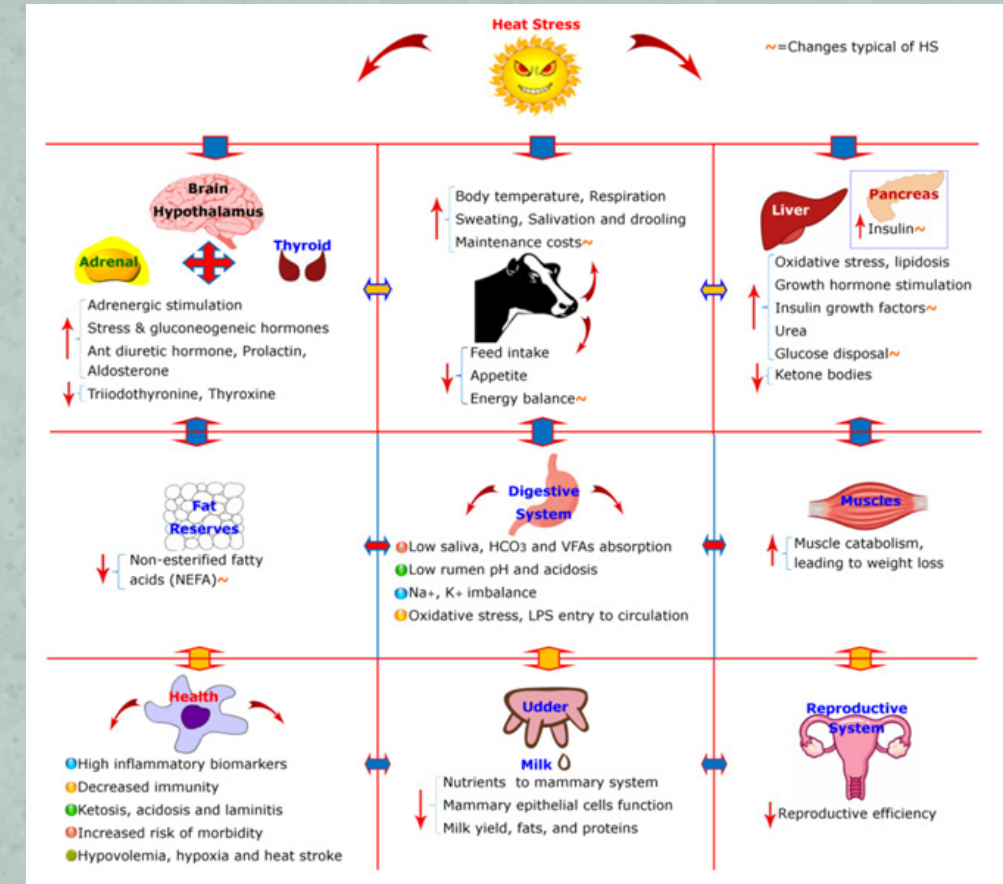


Figure 2. Summary of various physiological and biochemical changes associated with heat stress in dairy cows[2].



USV 1842



Funded by the European Union



Heat stress (compensation and adaptation mechanisms)

- ❑ An important role in the acclimatization process is played by compensation and adaptation mechanisms that are activated in case of heat stress.
- ❑ The humoral system plays a decisive role in the regulation of homeostasis via the **hypothalamus-pituitary-adrenal axis**.
- The key outcome of this interaction is the reduction of growth hormone and thyroxine levels, which reduces the activity of the basal metabolism.
- Hence, the initiation of the mentioned mechanisms can result in a decrease in animal productivity, but **reaching homeothermy and homeostasis** as survival conditions is the primary goal.
- **The identification and manipulation of genes** encoding heat shock proteins (for heat acclimation) from the genomes of tropical animals, potentially allows modification of the genotype by advanced biotechnological methods to adapt to climate change.

Feed intake

- ❑ **Reduced food intake** is one response to high ambient temperature.
- ❑ **Decreased appetite**, gut motility and rumination under increased heat stress were observed in ruminants.
- ❑ **Goats** are less sensitive, but reduce their feed intake when the ambient temperature is more than 10°C above the thermal comfort zone .

- ❑ **Pigs** reduce their feed intake by 11% when the temperature increases from 20 to 35°C.

- ❑ A 10°C temperature increase in **poultry** can reduce feed intake by 10%, affecting feed conversion and daily gain.

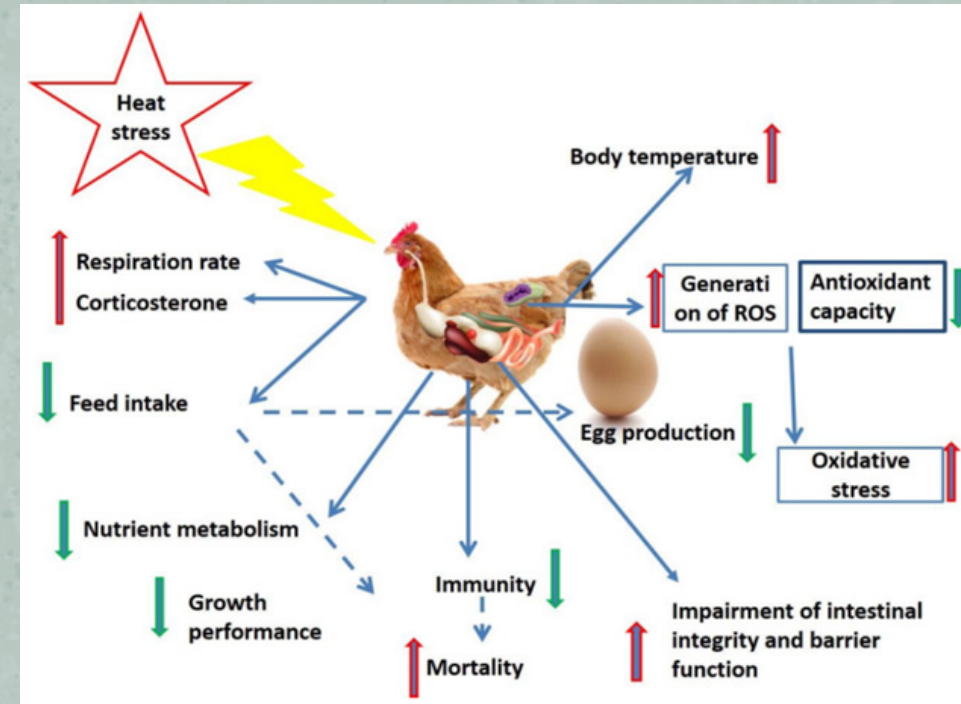


Figure 3. Effects of heat stress on poultry[3].



Funded by the
European Union



Production

- ❑ In all types of livestock, reduced feed intake due to heat stress leads to **reduced production**, which in turn leads to **financial losses**.
- In addition to heat, the production is also affected by the humidity of the environment, that is, their composition expressed through **the heat-humidity index (THI)**.
- **Lactating cows** begin to suffer from heat stress when the values of this index are above 72, while the content of milk proteins and milk fat decrease with its increase.
- **Small ruminants** (goats and sheep) show greater adaptability to warm and humid environments than large ones.
- **More productive breeds** show greater sensitivity to heat stress because they emit more metabolic heat.



Funded by the
European Union



Production

- With the increase in metabolic heat production caused by heat stress, there is a decrease in milk production.
- **Dairy cows** exposed to mild heat stress during lactation give up to 40% less milk, due to reduced feed intake, changes in metabolism and impaired development of the mammary gland.
- Heat stress during the last 50 days of pregnancy endangers the development of the udder and reduces the production of colostrum and milk.
- **Lactose and protein** content can be halved as a result of heat stress.
- **In goats**, under the influence of elevated temperature, a decrease of 12%, 3–10% and 4% was observed in growth, milk and meat production, respectively.



USV 1842



Funded by the European Union



Production

- ❑ Heat stress has an adverse effect on meat production.
- In ruminants, there is a decrease in growth, carcass mass and fat tissue thickness, but also lower meat quality.
- **Cattle in feedlots** are particularly sensitive because confinement limits their ability to adequately cool down (shade, water, wind) as well as due to exposure to rough radiating surfaces and feeding on high-energy feeds.
- Heat stress, through lower food intake and reduced availability of glycogen in the muscles, can be reflected in the appearance of **dark meat**.

Production

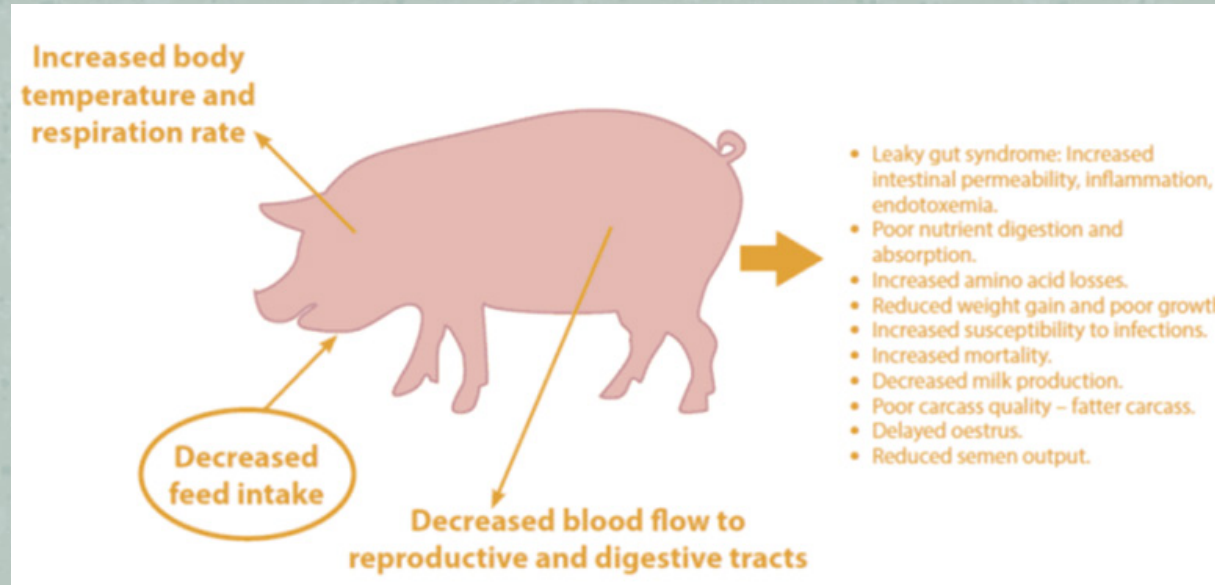


Figure 4. Physiological response and consequences of heat stress in pigs [4].

- ❑ In pigs, there is a decrease in growth, carcass weight, intramuscular fat content and meat quality when exposed to high temperature.
- Daily gain in pigs can decrease by 10% under the influence of high temperatures
- Heat stress reduces metabolic rate and alters post-absorptive metabolism independent of food intake.



Production

- **Poultry** exposed to heat stress increases energy consumption to maintain thermoneutral conditions at the expense of growth.
- **In broilers** under heat stress, there is a decrease in growth, feed conversion rate, breast muscle mass and protein content in meat.
- Egg strength, mass, daily production and feed intake are most influenced by heat stress in **laying hens**.



Reproduction

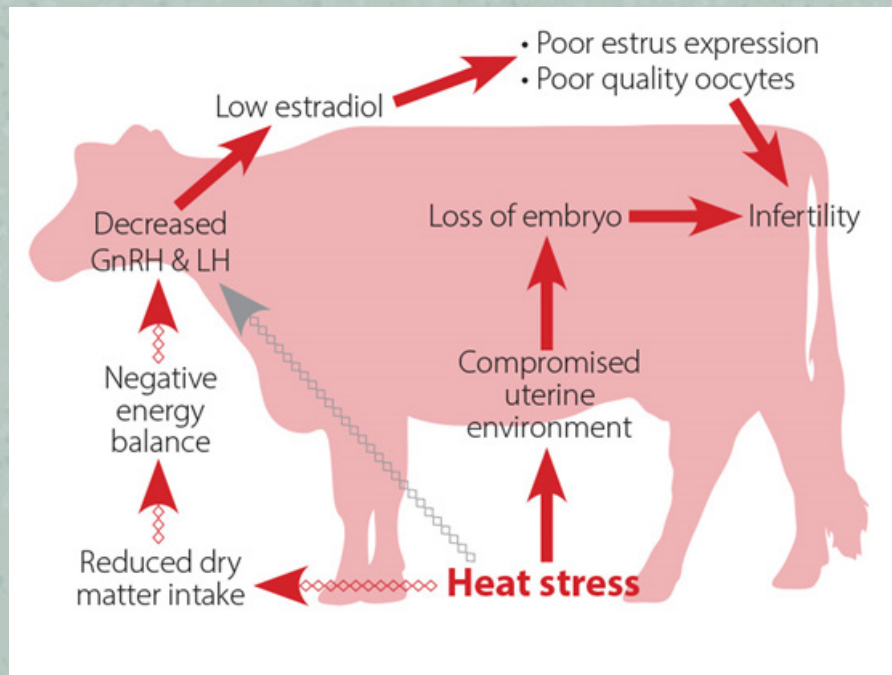


Figure 5. The influence of heat stress on reproductive disorders[5].

- ❑ Heat stress affects reproduction in both sexes.
- **In females**, heat stress reduces the period of estrus and fertility while increasing the incidence of anestrus and embryonic death.
- **In males**, heat stress causes a decrease in sperm quality, testicular volume and the amount of fertile semen.
- Pregnant and lactating
- **Conception rate** can be reduced by 10-20% with losses during pregnancy

Reproduction

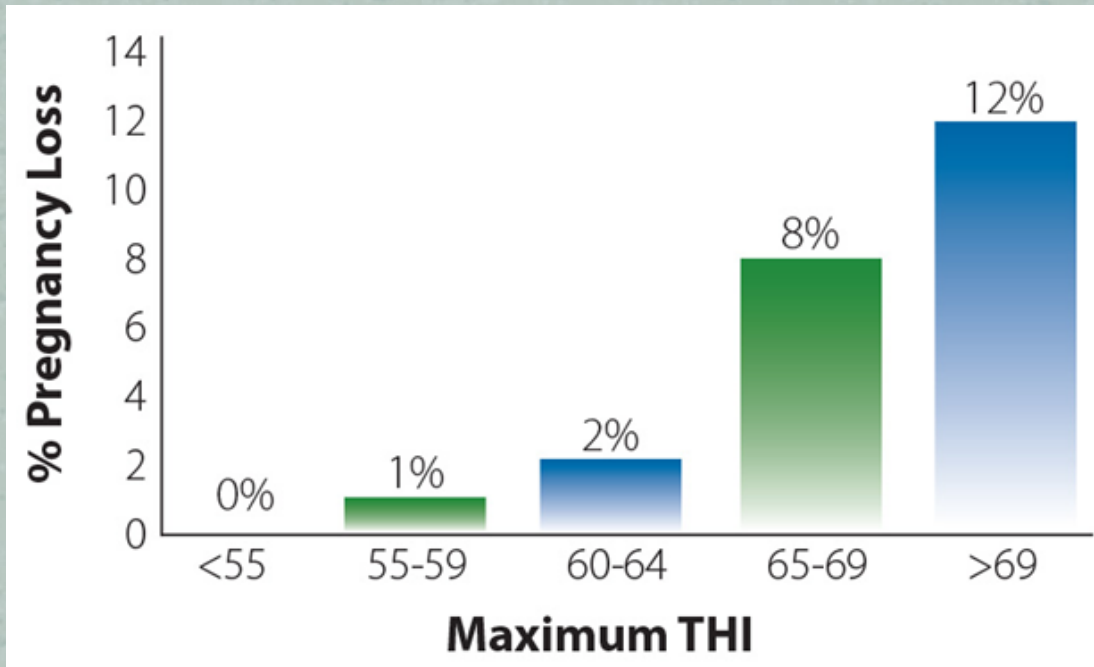


Figure 6. Relationship between THI and abortion rate

❑ They are **with broilers** males more sensitive than females to heat-induced infertility.

➤ In **laying hens**, it leads to a delay in ovulation, reduces the quality of yolk and pregnancy rate.

❑ In **sheep**, exposure to heat stress significantly impairs fertility and reduces seed production and ram quality, resulting in fewer lambs per ewe.

➤ Reduced birth weight **of lambs** and poor udder development in ewes due to heat stress during pregnancy can reduce survival and weaning weight of lambs.

Reproduction

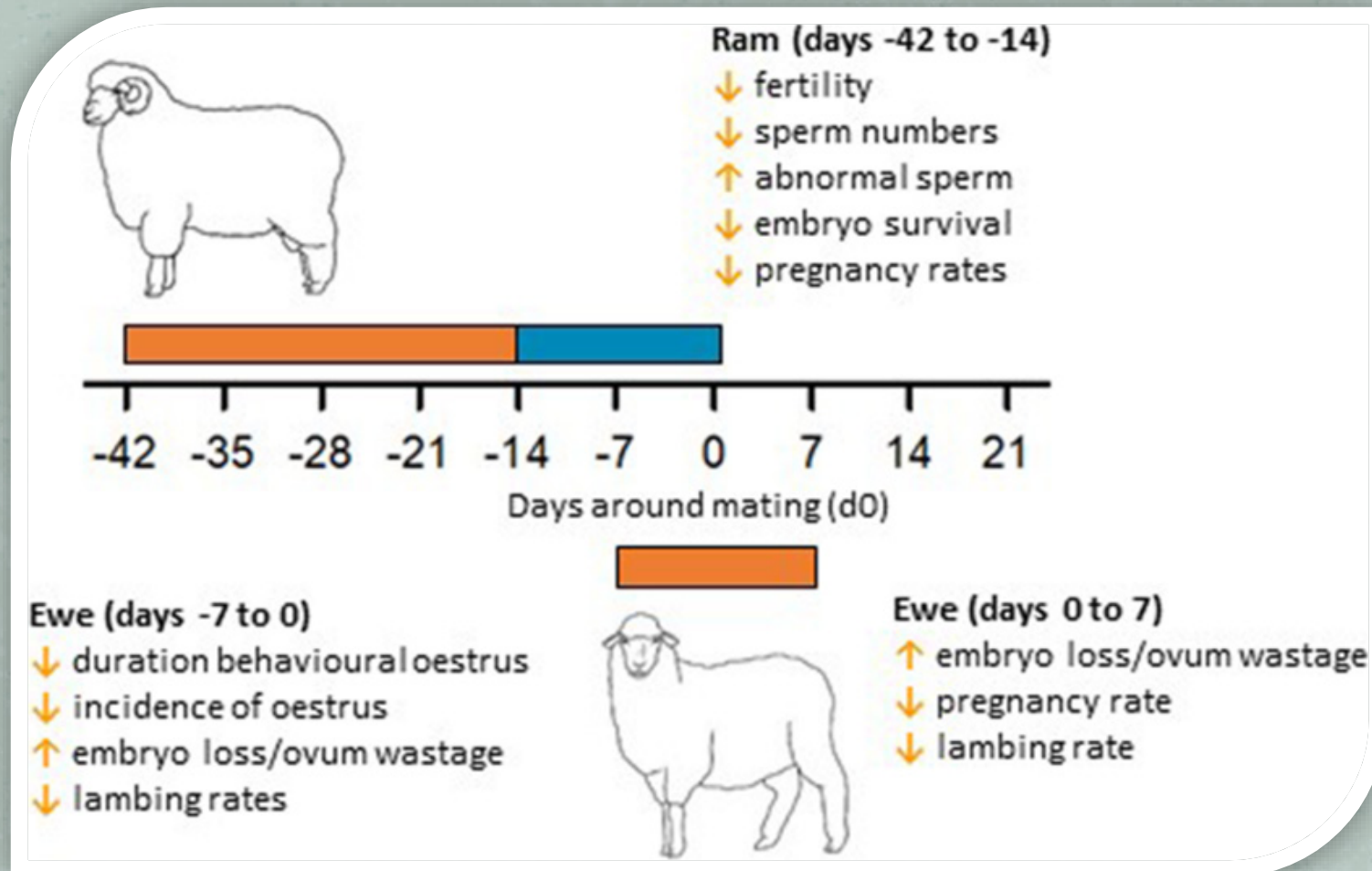


Figure 7. Effects of heat stress on the fertility of rams and ewes before and during the mating period. Temporal normothermic (blue) and hyperthermic (orange) temperatures before mating [6].



USV 1842



Funded by the
European Union



Health

- ❑ The **immune system** plays a key role in ensuring proper health, but heat stress can significantly disrupt its defensive function.
- ❑ High temperatures and changes in the rainfall regime favor the development and **spread of pathogens** and consequently can change their distribution and lead to the emergence of new diseases.
- ❑ As a result of the immunosuppressive effect of heat stress, cattle become more susceptible to disease, leading to increased **morbidity and mortality rates** in herds.



USV 1842



Funded by the European Union

Health



❑ **Climate change** affects animal health directly and indirectly.

1) **Direct impacts** include vector-borne diseases, as well as those caused by water (eg flooding), soil, temperature, humidity, or transmitted by rodents.

2) **Indirect impacts** include those that lead to adaptive changes in animals, modification of microbial communities, changes in the host's immune and general response to pathogens, starvation and food poisoning .



Health

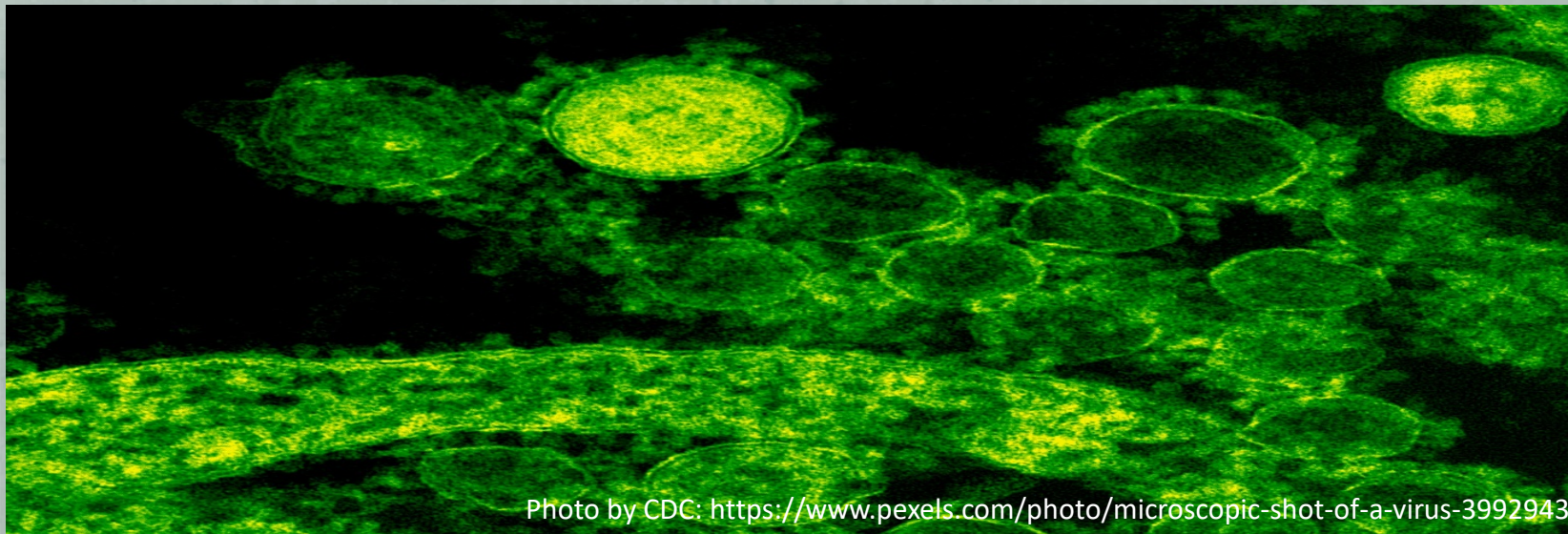


Photo by CDC: <https://www.pexels.com/photo/microscopic-shot-of-a-virus-3992943/>



- ❑ The **intensity** of the impact of climate change on livestock health depends on several factors, such as:
 - Genotype,
 - Specific and non-specific resistance of animals to diseases,
 - Rearing area,
 - Characteristics of pathogens.



Funded by the
European Union



Mortality

- ❑ Increased mortality of farm animals as a result of heat stress can have a significant negative economic effect.
- ❑ Studies in dairy cows and pigs show that heat stress increases the mortality rate.
- ❑ Hot and humid weather is more dangerous to the life of cows and pigs compared to hot and dry weather
- ❑ Compared to mammals, poultry have a higher and more variable body temperature and are more susceptible to heat stress.
- ❑ Temperatures up to 27 °C or body temperatures up to 41 °C can be considered suitable for raising chickens.
- ❑ Lethal outcomes in chickens occur when the body temperature increases by 4 °C.



USV 1842



Funded by the European Union



Sources:

- [1] Kummu , M., Heino , M., Taka, M., Varis , O., & Viviroli , D. (2021). Climate change risks pushing one-third of global food production outside the safe climatic space, One Earth 4, 5, 720-729. <https://doi.org/10.1016/j.oneear.2021.04.017> .
- [2] Sammad , A., Wang, YJ, Umer , S., Lirong , H., Khan, I., Khan, A., Ahmad, B., & Wang, Y. (2020). Nutritional Physiology and Biochemistry of Dairy Cattle under the Influence of Heat Stress: Consequences and Opportunities. Animals 10, 793.
- [3] Shehata , AM, Saadeldin , IM, Tukur , HA, & Habashy , WS (2020). Modulation of Heat-Shock Proteins Mediates Chicken Cell Survival against Thermal Stress. Animals 10, 2407.
- [4] <https://www.chemunique.co.za/swine/preventing-heat-stress-in-pigs/>
- [5] <https://www.techmixglobal.com/repro-heat-stress/>)
- [6] Van Wettere , WHEJ, Kind, KL, Gatford , KL, Swinbourne , AM, Leu , ST , Hayman, PT, Kelly, JM, Weaver, AC, Kleemann, DO , & Walker, SK (2021). Review of the impact of heat stress on reproductive performance of sheep. J Animal Sci Biotechnol 12, 26.



USV 1842



Funded by the
European Union



INDIRECT IMPACT OF CLIMATE CHANGE ON LIVESTOCK PRODUCTION

FORAGE QUALITY, WATER, SEASONAL VARIATION
AND EXTREME CLIMATE EVENTS

Dr. Dušica Ostojić Andrić

Introduction

- ❑ Climate change scenarios predict a **temperature rise** of 1.1°C to 6.4°C by the century's end.
- ❑ Changes in **precipitation patterns** and more frequent **extreme weather** events pose risks to food and water security in livestock farming.
- ❑ **Indirect effects** of climate change include soil fertility, water availability, fodder yield, quality, and pathogen spread.
- ❑ These factors must be considered alongside direct impacts for a comprehensive understanding of climate change's implications on animal agriculture.



Forage Quality

- ❑ Adequate nutrition is crucial for animal health, growth, production, and reproduction.



- ❑ Climate change alters forage quantity and quality mostly due to increased CO₂ and temperature, impacting animal husbandry differently based on system, location, and species.

- ❑ Significant influencing factors are:
 - precipitation patterns,
 - extreme climatic events,
 - variations in production and
 - water supply.



TAGEM
R&D AND INNOVATION



Faculty of Agriculture
and Technology
University of South Bohemia
in České Budějovice



USV 1842



Funded by the
European Union

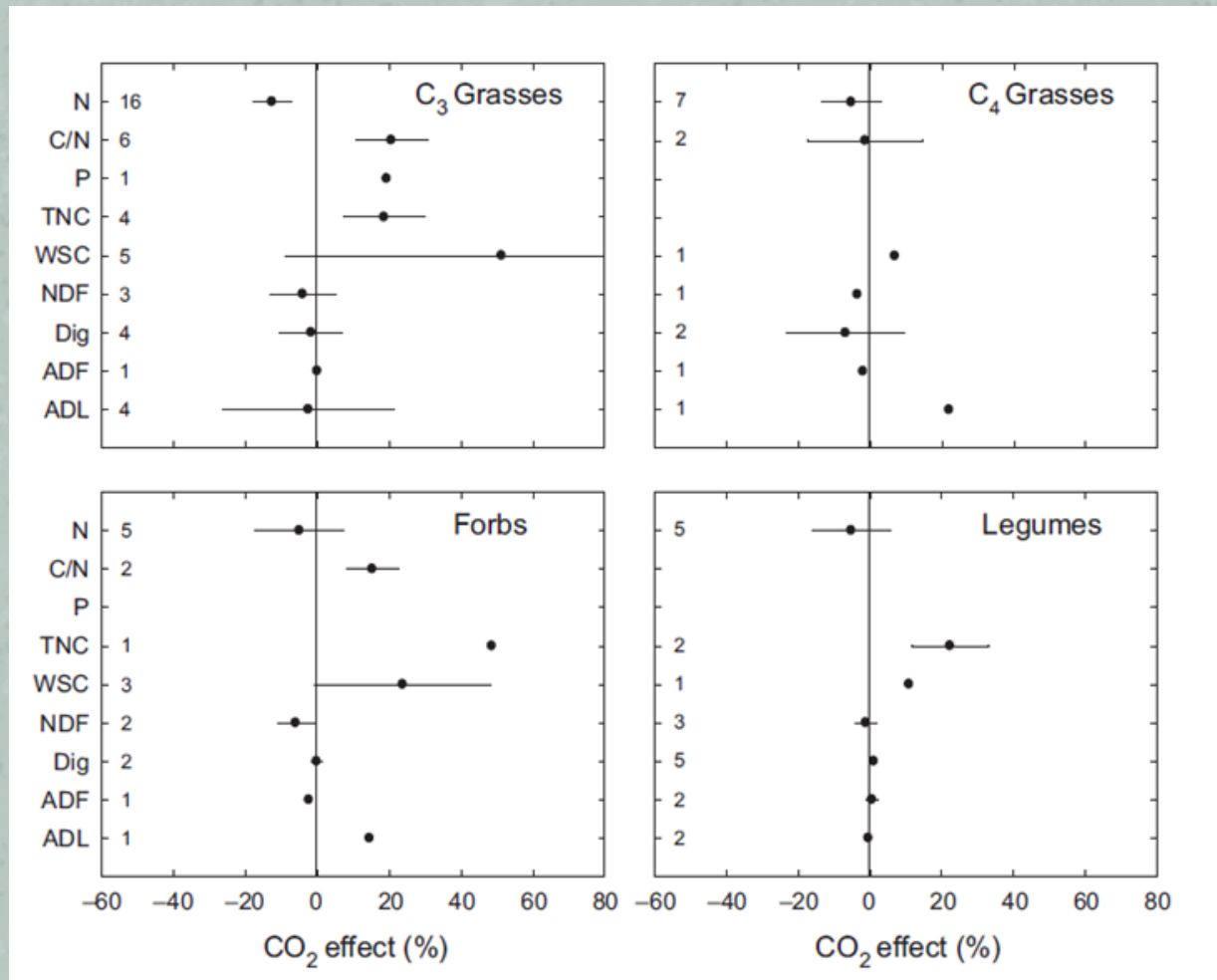


Forage Quality



- ❑ Climate change indirectly impacts livestock nutrition by altering the **physical and chemical traits of plants** used in feed.
- ❑ This alteration affects the **quality of livestock feed**, depending on the extent of warming and severity of drought.
- ❑ Plants respond to heat stress in diverse physical and chemical ways, influencing **nutritional parameters** (fiber, protein, nitrogen, carbohydrates, and minerals).

Forage Quality



❑ The **interaction** between climatic factors and forage quality is complex, as illustrated in Figure 1

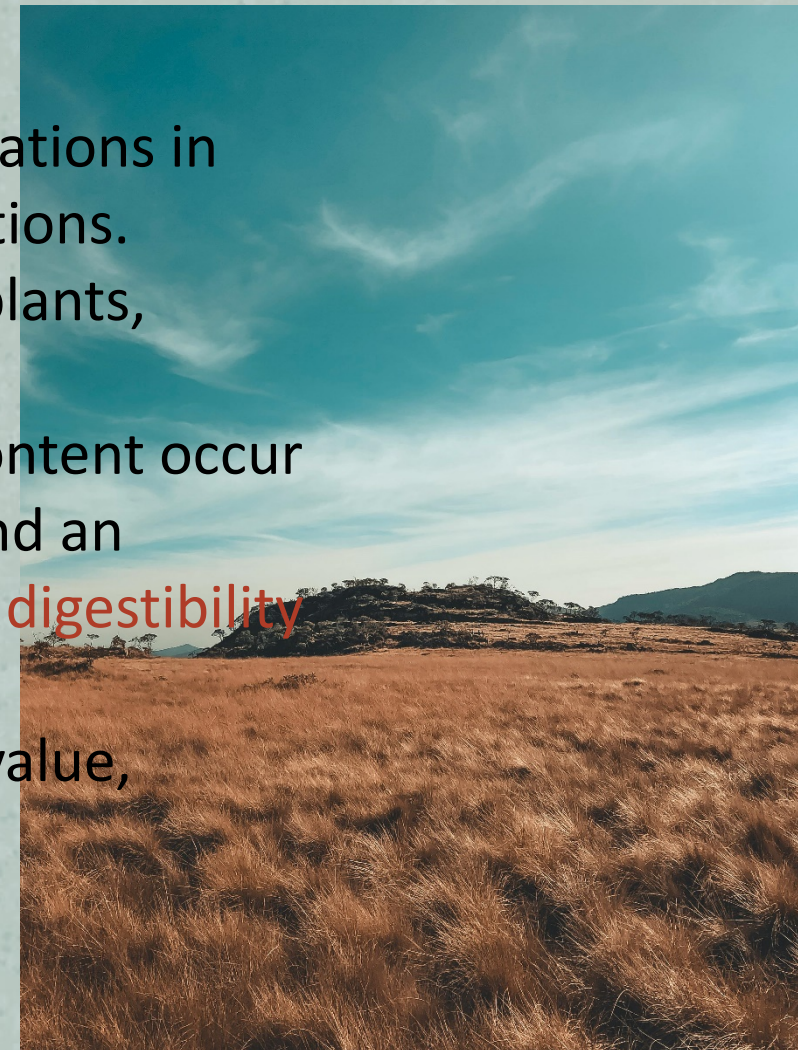


Figure 1. The average effect of increasing CO₂ on the key forage quality indicators [1].



Forage Quality

- ❑ Dry conditions and high temperatures influence variations in nitrogen and water-soluble carbohydrate concentrations.
- ❑ Extreme weather causes premature tissue aging in plants, drastically reducing forage quality.
- ❑ Faster plant maturation and reduced tissue water content occur even with mild heat stress, leading to lignification and an unfavorable stem-to-leaf ratio, negatively impacting digestibility and quality.
- ❑ Higher temperatures can decrease feed nutritional value, potentially increasing methane production





TAGEM
R&D AND INNOVATION



Faculty of Agriculture
and Technology
University of South Bohemia
in České Budějovice



USV 1842



Funded by the
European Union



Forage Quality: C3 and C4 crops

- ❑ Forage refers to the edible parts of plants that can be grazed by animals or harvested for food.
- ❑ **Two main types** of forage plants are legumes and grasses, categorized based on leaf anatomy into **cold season (C3)** and **warm season (C4)** groups.
- ❑ Elevated CO₂ levels affect crop growth differently:
 - **C4 crops** (maize and sorghum) may not directly respond to CO₂ increase, but may benefit indirectly from drought conditions
 - **C3 crops** (soybean and wheat) show improved yields under increased CO₂ concentrations
- ❑ **Rainfall, temperature, and extreme weather events** (drought), influence feed availability, with certain crops like rice, soybeans, sorghum, and corn benefiting from increased rainfall
- ❑ **Temperature increases** generally favor C4 species, although the extent of these benefits varies based on location, plant species, and production technologies

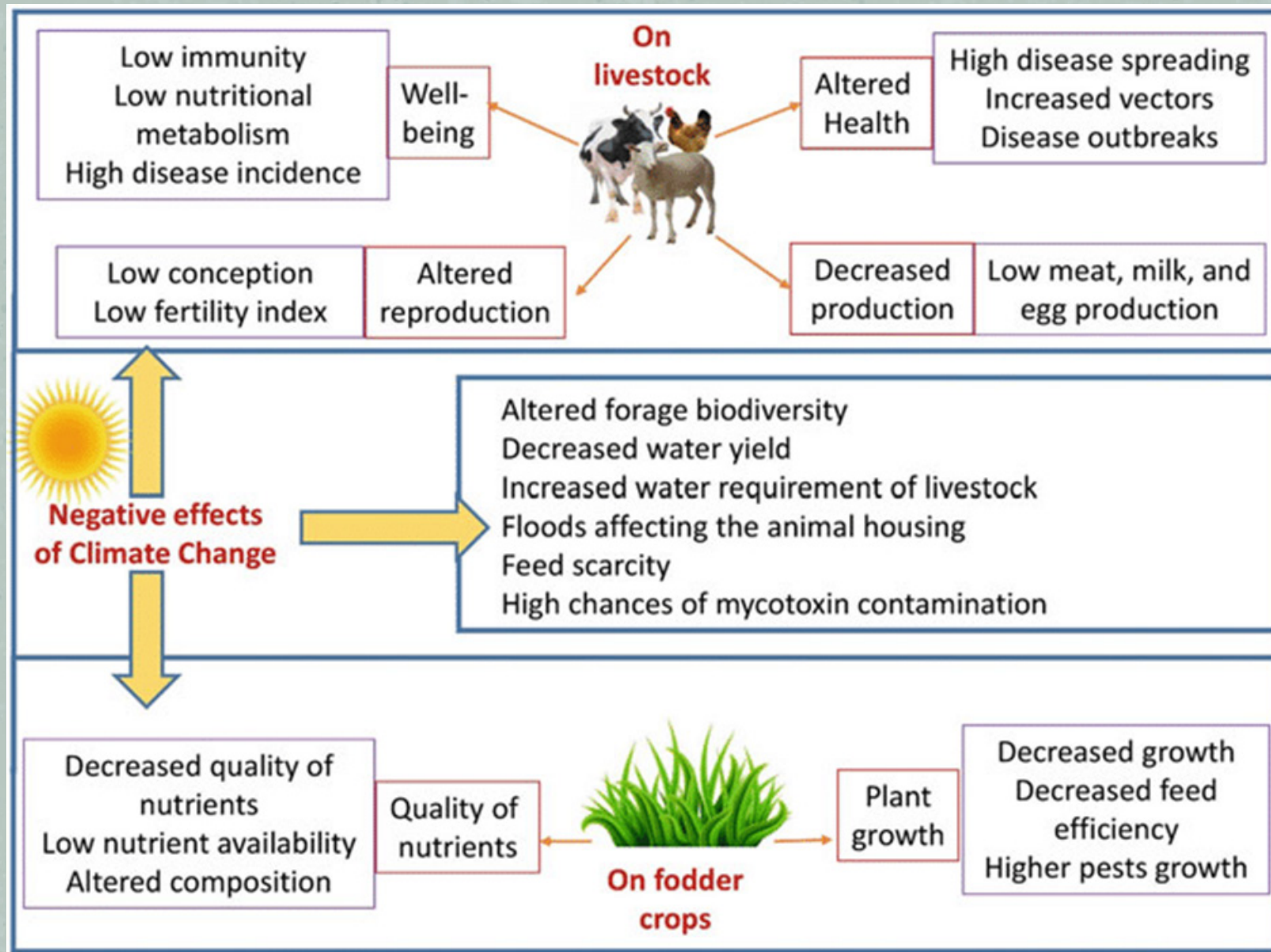


Figure 2. Negative impacts of climate change on livestock [2]



USV 1842



Funded by the
European Union



Forage Quality

- ❑ **Drought** leads to significant yield reductions, especially in warm regions, impacting crops like maize and winter wheat, particularly during poor yield years.
- ❑ **Higher temperatures at higher latitudes** may **enhance crop adaptability** and extend the growing season
- ❑ **Higher temperatures at lower latitudes** may exacerbate **water stress**.
- ❑ **Higher temperatures and drier conditions** favor C4 species but can also increase toxicity in certain plants.
- ❑ **Elevated CO₂** concentrations can **reduce protein and mineral** concentrations in some plants and increase toxicity in others.
- ❑ **Elevated CO₂** levels also favor C3 plants and promote the spread of trees over grasses, posing risks to ecosystem balance.



Forage Quality: grasslands and pastures

- ❑ The increase in average temperature significantly alters the distribution of biomes and the **composition** of grasslands and pastures.
- ❑ Changes in rainfall patterns and more frequent droughts may lead to **shorter intervals of pasture growth**.
- ❑ Fluctuations in temperature, CO₂ concentration, and nitrogen deposition contribute to **lower pasture productivity**.
- ❑ Pasture systems face heightened vulnerability to climate change due to **limited adaptation options**, particularly in arid and semi-arid grazing areas.
- ❑ Increased temperatures and reduced rainfall are expected to **lower pasture yields** and worsen soil degradation in these regions.





TAGEM
R&D AND INNOVATION



Faculty of Agriculture
and Technology
University of South Bohemia
in České Budějovice



Funded by the
European Union



Water



- ❑ **Water scarcity** varies depending on availability and demand, with **agriculture** being the **largest consumer**, accounting for 69% of global water use
- ❑ In the livestock industry, water is essential for animal consumption, feed production, and product processing.
- ❑ **Animal husbandry** drives about 22% of the world's total evapotranspiration from agricultural land and **41% of overall water use**.
- ❑ As the human population grows and demand for livestock products increases, water scarcity is expected to become a significant limiting factor for agricultural production.



Water

- ❑ Climate change is expected to impact **water availability and livestock water usage**
- ❑ Rising temperatures may lead to **increased water consumption** per head and per hectare, including irrigation water usage
- ❑ **Rising sea levels** pose a challenge for **water desalination** efforts
- ❑ **Competition for water** among livestock, crops, and non-agricultural uses will intensify, requiring highly efficient production technologies to manage water scarcity
- ❑ **Water quality** is predicted to decrease due to rising temperatures, sea levels, and increased sediment, nutrient, and pollutant loads from heavy rainfall.
- ❑ **Poor water quality** can diminish water and feed consumption in animals and pose **health risks** to them.



Seasonal Variations and Extreme Climate Events

- ☐ Climate change may alter the seasonal patterns and availability of resources and crops, impacting livestock.
- ☐ Increased heatwave frequency and duration are expected to subject animals to more heat stress.
- ☐ Grazing and livestock management may face challenges due to changes in seasonal forage patterns.
- ☐ Extreme drought poses a threat to animal feed production, necessitating adaptive measures.
- ☐ Alterations in snowmelt timing affect water availability patterns throughout the year, further impacting feed supply.



TAGEM
R&D AND INNOVATION



Faculty of Agriculture
and Technology
University of South Bohemia
in České Budějovice



USV 1842



Funded by the
European Union



Seasonal Variations and Extreme Climate Events

- ❑ **Heat waves and droughts** in the continental climate region of the Pannonian Plain significantly impact natural grasslands.
- ❑ A **predictive analysis** of climate change at five locations in Serbia under two GHG emission scenarios - RCP4.5 and RCP8.5. shown that natural grassland vegetation will face more frequent droughts and extreme heat in the future (Table 1, Figure 3).
- ❑ Climate change poses a risk to the **survival of grass plant species**, particularly those from northern temperate climates, which are crucial components of sown lawns for coarse fodder production in Serbian meadows and arable fields.
- ❑ However, **natural diversity** may lead to the development of drought tolerance and the spread of species resistant to high temperatures and water scarcity, such as **weeds and lower-quality species**.



Seasonal Variations and Extreme Climate Events

Table 1. Simulated number of drought days on selected localities in Serbia [3]

Scenario	Period	Rimski Šančevi	Valjevo	Kragujevac	Negotin	Leskovac
RCP 4.5	1986–2005	101	95	100	106	101
	2016–2035	101	97	101	107	102
	2046–2065	103	99	103	109	105
	2080–2100	103	99	103	108	105
RCP 8.5	1986–2005	100	94	100	106	102
	2016–2035	101	96	101	106	101
	2046–2065	102	99	103	108	104
	2080–2100	106	103	107	111	109

Seasonal Variations and Extreme Climate Events

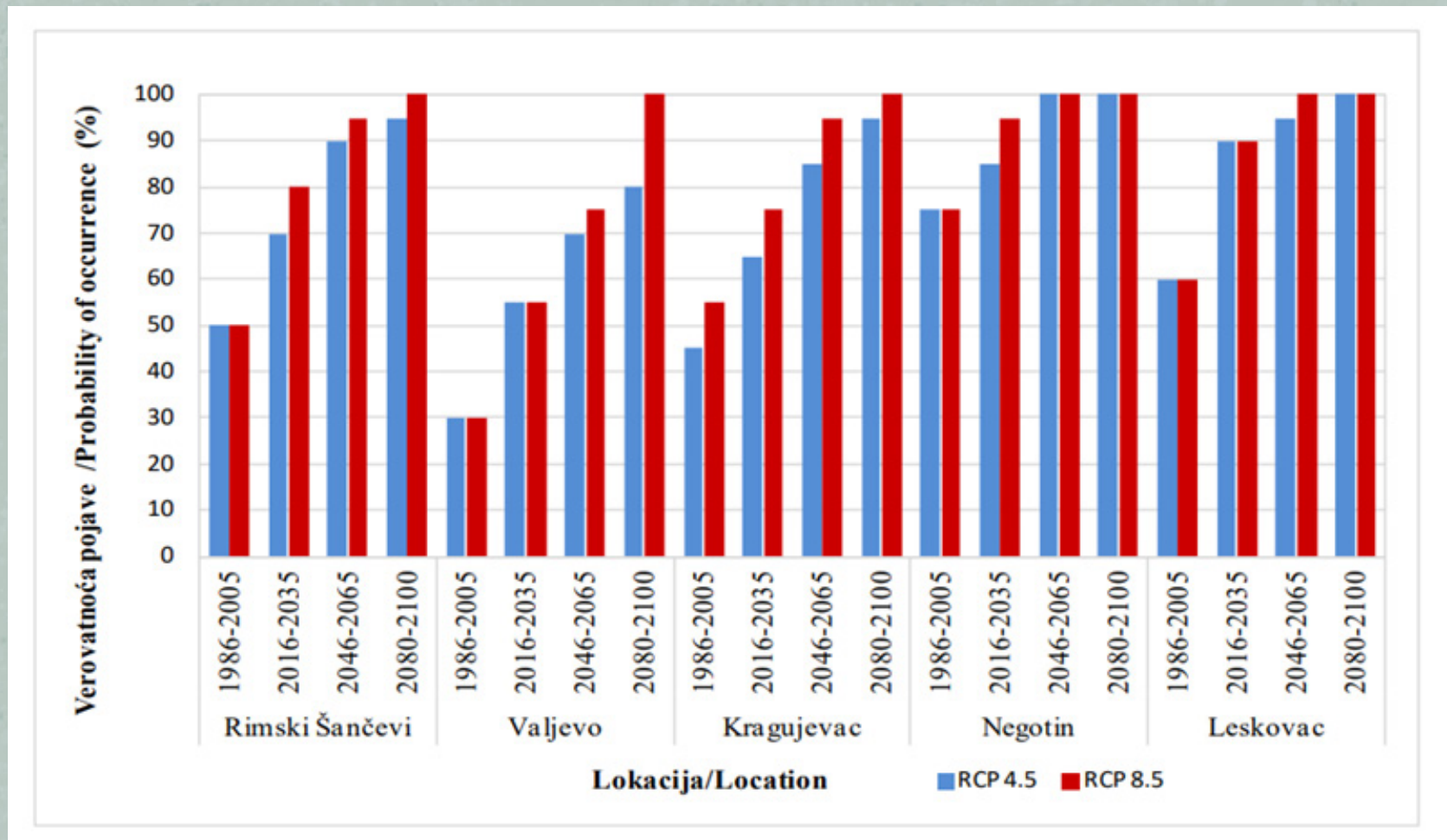


Figure 3. Probability of occurrence (%) of max. daily temperature (> 30°C) for more than 30 days [3].



TAGEM
R&D AND INNOVATION



Faculty of Agriculture
and Technology
University of South Bohemia
in České Budějovice



USV 1842



Funded by the
European Union



Seasonal Variations and Extreme Climate Events

- ❑ Seasonal variations and extreme climatic events can **increase the morbidity and mortality** of livestock.
- ❑ **Prolonged droughts** lead to water and pasture shortages, reducing livestock immunity against infectious diseases.
- ❑ **Resource scarcity** drives grazing animals into areas with a higher risk of **infectious diseases**, such as wildlife reserves, increasing animal-to-animal interaction and **disease transmission**.
- ❑ Livestock may face the risk of exposure to **new pathogens** due to increased contact with **wild animals** in grazing areas resulting from deforestation and changes in land use.





Funded by the
European Union



Sources:

- [1] Dumont, B., Andueza, D., Niderkorn, V., Luscher, A., Porqueddu, C., & Picon-Cochard, C. (2015). A meta-analysis of climate change effects on forage quality in grasslands: Specificities of mountain and Mediterranean areas. *Grass Forage Sci.* 70, 239-254
- [2] Jack, A. A., Adegbeye, M. J., Reddy, P. R. K., Elghandour, M. M. M. Y., Salem, A. Z. M., & Adewumi, M. K. (2022). Ruminant Productivity Among Smallholders in a Changing Climate: Adaptation Strategies. In: M. Lackner, B. Sajjadi, W.Y. Chen (Eds.) *Handbook of Climate Change Mitigation and Adaptation* (pp. 1-41). Springer. Cham. https://doi.org/10.1007/978-3-030-72579-2_148
- [3] Stričević, R., Simić, A., Vujadinović-Mandić, M., & Sokolović, D. R. (2021). Uticaj klimatskih promena na potrebe prirodnih travnjaka za vodom u Srbiji. *Journal of Agricultural Sciences* 66, 3, 291-307.



USV 1842



Funded by the
European Union



DIRECT EFFECTS OF LIVESTOCK PRODUCTION ON GHG EMISSIONS

ENTERIC FERMENTATION, MANURE MANAGEMENT
AND ENERGY CONSUMPTION

Dr. Dušica Ostojić Andrić

Climate Focused Agricultural Vocational Education (CLIAVE) www.cliave.net



Introduction



- ❑ Livestock production is a significant source of greenhouse gas emissions (GHG) 14.5% of total anthropogenic emissions, i.e. 8.1 gigatons of CO₂ equivalent per year.
- ❑ GHG trap heat in the Earth's atmosphere, causing rising temperatures and climate changes.
- ❑ Methane (CH₄), nitrous oxide (N₂O) and carbon dioxide (CO₂) are the **three primary greenhouse gases** released by livestock.





Introduction

- ❑ **Carbon dioxide** is released primarily from the combustion of fossil fuels in power machinery and from the burning of biomass through microbial decomposition.
- ❑ Carbon dioxide emissions can also result from the conversion of arable land into permanent grassland (through land use change) or from adjustments in agricultural land management.
- ❑ **Methane** is produced during the decomposition of organic material under anaerobic conditions (during enteric fermentation of ruminants, storage of manure, or organic waste from the processing industry).
- ❑ **Nitrogen oxides** are released during the microbial transformation of nitrogen in the soil or in manure.

Introduction



- ❑ The **carbon footprint** measures CO₂ and other GHG emissions released during human activities like energy use, transportation, and food production.
- ❑ It quantifies total GHG emissions by converting them into **CO₂eq** based on their **global warming potential (GWP)**.
- ❑ **CO₂ equivalent (CO₂eq)** serves as a unit of measurement for carbon dioxide and other greenhouse gases (GHGs) contributing to global warming.
- ❑ By using CO₂eq, it's possible to **compare emissions** of different GHGs and **track progress** in reducing total greenhouse gas emissions over time.
- ❑ **Methane** has a GWP value 28-36 times that of CO₂ over 100 years, while **nitrous oxide** has a GWP value 265 times greater than CO₂.



Funded by the
European Union

Introduction

- Methane (CH₄), nitrous oxide (N₂O), and carbon dioxide (CO₂) constitute 50%, 24%, and 26% of emissions, respectively, in the animal products supply chain (Figure 1).

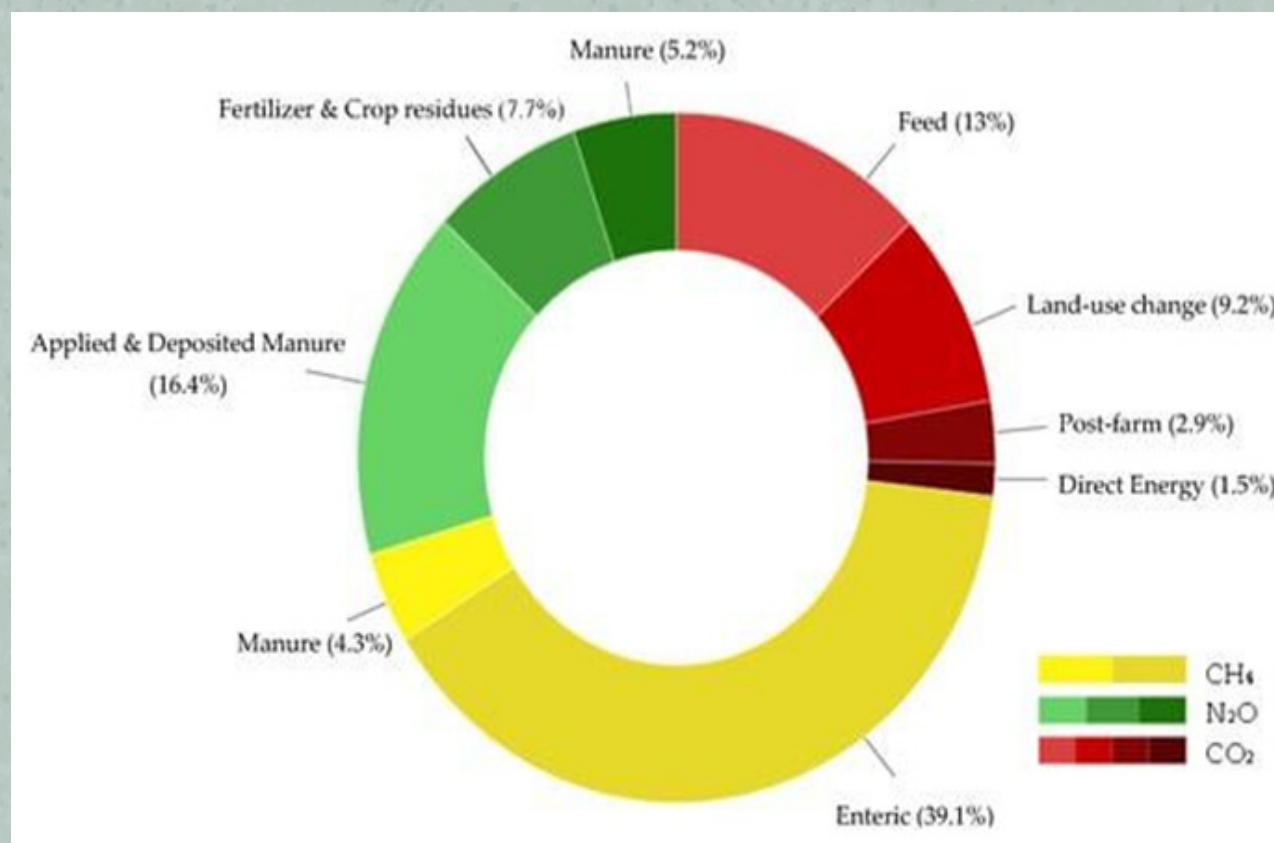


Figure 1. GHG emissions from different sources in livestock [1].

Introduction



- ❑ **Cattle** contribute about 62% of total livestock emissions, with dairy and beef cattle emitting similar amounts (Figure 2).
- ❑ **Other species**, including pigs, poultry, buffalo, and small ruminants, individually account for 7-11% of emissions.

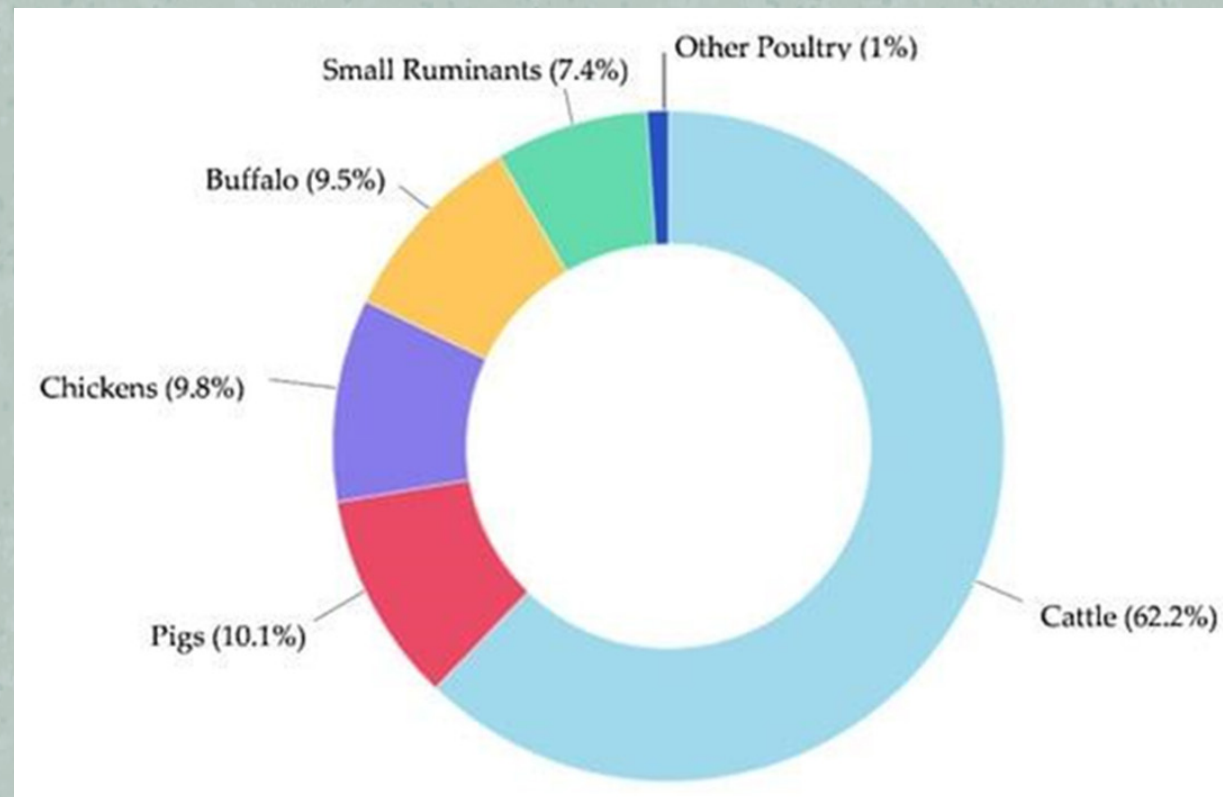


Figure 2. GHG emissions by livestock species [2].





Introduction

- ❑ Comparing emissions based on **protein production** reveals varying intensity levels among different types of animal products.
- ❑ **Buffalo meat has the highest emissions intensity**, averaging 404 kg of CO₂eq per kg of protein produced.
- ❑ **Beef production** follows with an average of 295 kg CO₂eq per kg protein, while meat and milk from small ruminants and buffalo milk emit 201, 148, and 140 kg CO₂eq per kg protein, respectively.
- ❑ Products with the **lowest emission intensity** (less than 100 kg CO₂eq per kg protein) include cow milk, poultry meat and eggs, and pork.



Introduction



- ❑ **Direct emissions** originate from animal husbandry, encompassing harmful gas release through enteric fermentation and manure, and may include emissions from accompanying energy consumption.
- ❑ **Indirect emissions** primarily stem from animal feed production and associated land use changes.
- ❑ The **relative proportions** of direct and indirect emissions remain **uncertain**, with no conclusive determination on which type holds the larger share.



Climate Focused Agricultural Vocational Education (CLIAVE) www.clieve.net



Enteric Fermentation



- ❑ In the digestive system of ruminants (Figure 3), enteric fermentation occurs, involving the decomposition of organic matter, primarily **fibrouscellulosic** types, by the **microflora** present.
- ❑ This unique process **converts** hard to degrade substances like **cellulose and lignin** into nutritionally valuable substances for human consumption.

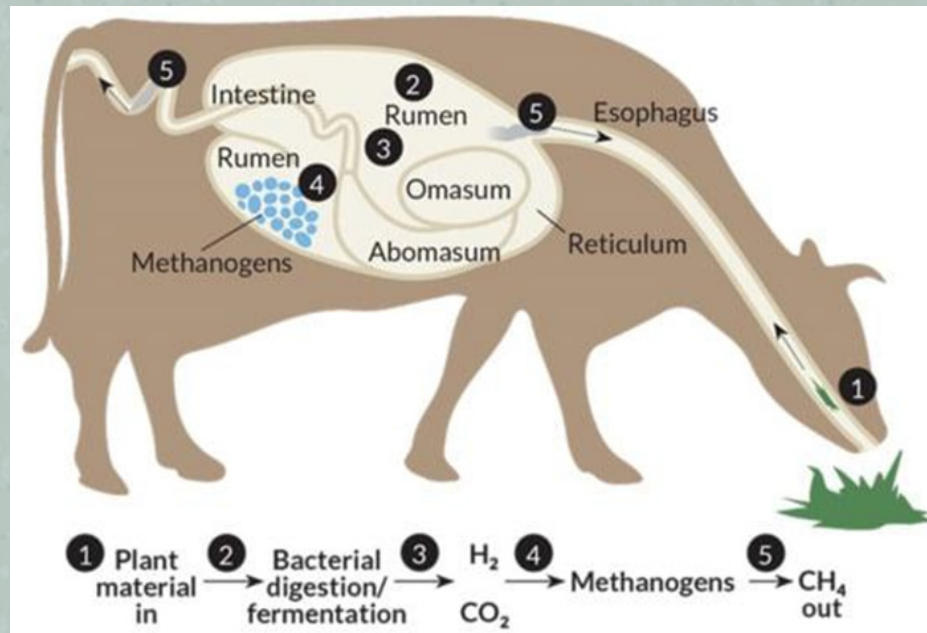


Figure 3. Enteric fermentation and methanogenesis in ruminants [3].

- ❑ **Enteric fermentation** also produces **methane**-harmful gas that ruminants release into the environment through exhaling, belching, and defecating.
- ❑ **Ruminants** are the **primary contributors** to methane emissions among domestic animals.

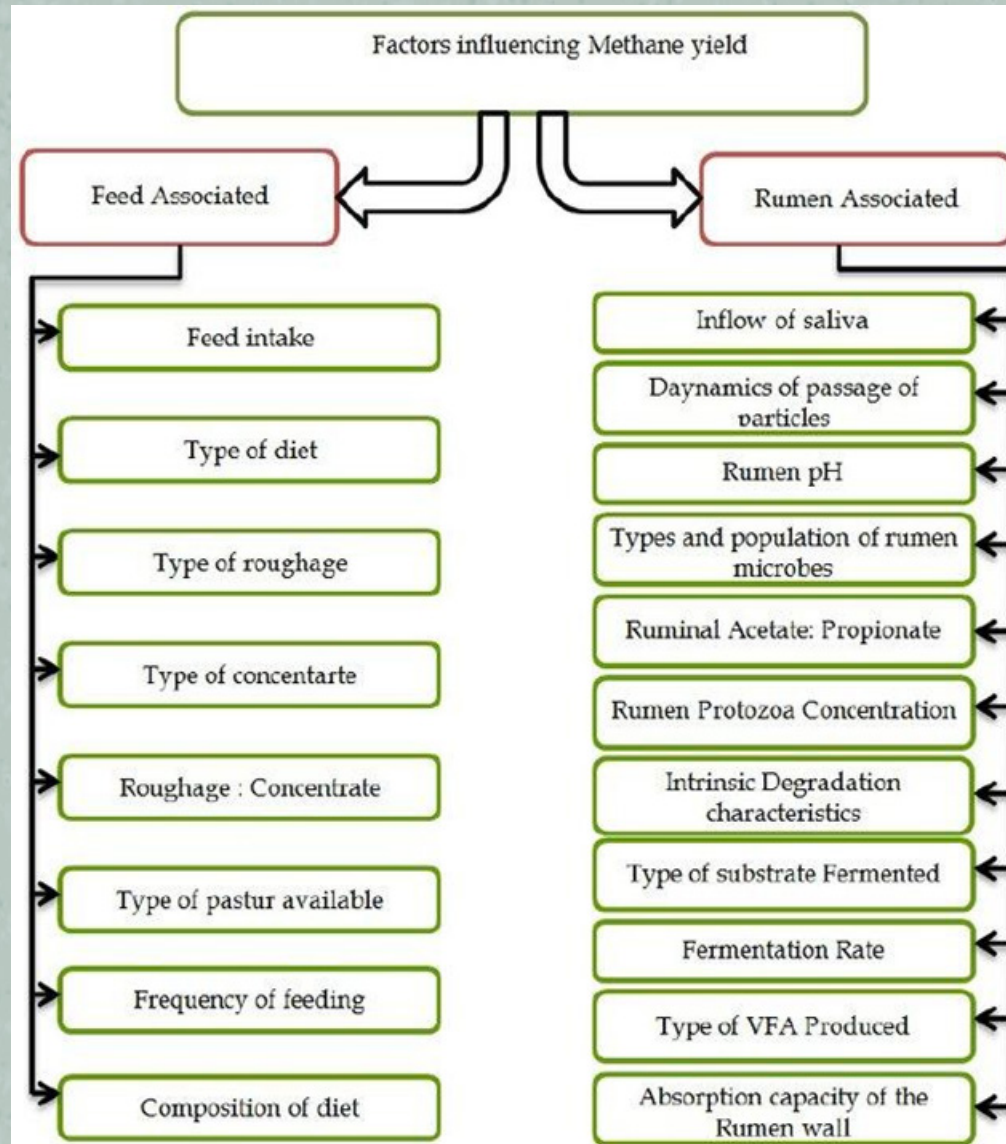
Enteric Fermentation



- ❑ **Methane from enteric fermentation** contributes to 39% of total GHG emissions (Figure 1) and has a 28 times higher atmospheric warming potential than CO₂.
- ❑ **Non-ruminants** also produce methane, but in significantly smaller quantities compared to ruminants.
- ❑ Given ruminants' significant methane contribution and its negative impact on productivity, **effective mitigation strategies** are crucial.
- ❑ These strategies aim to **minimize methane production** while maintaining or improving animal productivity and welfare.
- ❑ **Factors influencing methane production** in ruminants include feed intake, nutrient quantity, and quality, with higher digestibility leading to reduced methane synthesis and increased animal productivity (Figure 4).
- ❑ Research explores **advanced molecular and biochemical techniques** alongside dietary and management adjustments and manipulation of rumen activity.



Enteric Fermentation



□ **Increased feed intake** results in higher methane emissions, while factors such as animal **health status** and **feed additives** also impact emissions.

□ Ruminant species, production systems, and regional characteristics collectively influence the rate at which food energy is converted into methane.

Figure 4. Factors affecting methanogenesis in ruminants [4].



Manure Management



- ❑ The intensification and specialization of livestock production are leading to increased manure production significant source of GHGs such as methane and nitrous oxide.
- ❑ Manure contributes nearly 10% of total GHG.
- ❑ Unlike enteric fermentation, which predominantly releases methane, manure is a substrate for the release of both, NO₂ and CH₄.
- ❑ The share of CH₄ and NO₂ emissions from manure to total GHG emissions is 4.3% and 5.2%,
- ❑ Cattle and pigs are the primary sources of methane emissions from manure, as depicted in Figure 5.

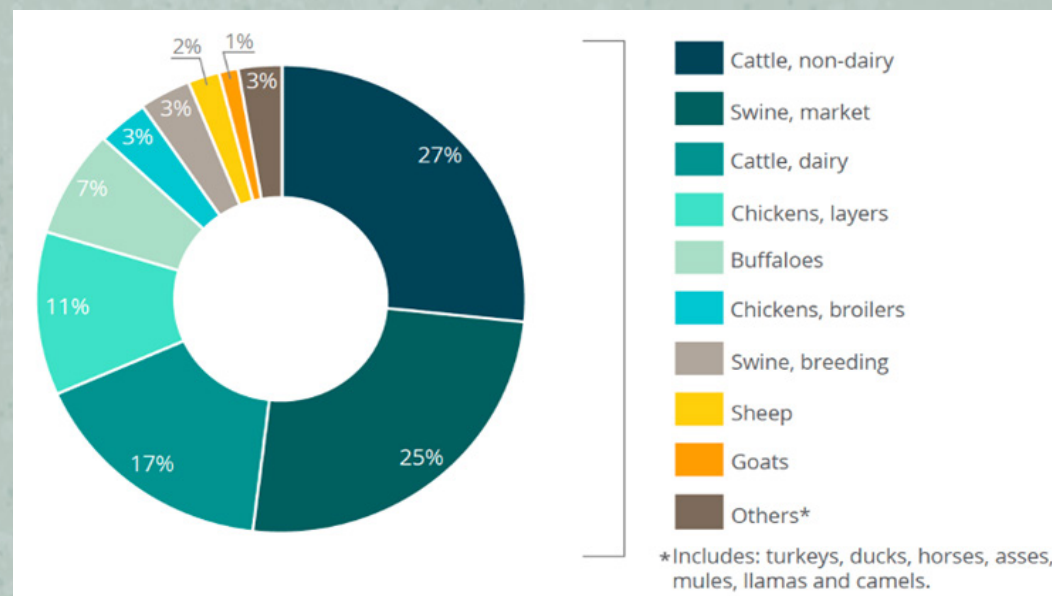


Figure 5. Contribution of the different livestock sectors to emissions from manure [5].





Manure Management



- ❑ The emissions of GHG from manure are influenced by **environmental conditions**:
 - air temperature and humidity,
 - duration of manure storage and handling,
 - type of animal feed.
- ❑ **Methane formation** is favored by **anaerobic conditions**,
- ❑ Both **aerobic and anaerobic conditions** are necessary for the formation of **nitrogen oxides** from ammonia.



Manure Management



- ❑ The **highest levels** of **nitrogen oxides** are emitted when manure is deposited in a **solid state or spread** on the ground.
- ❑ When manure is stored in a **liquid state** (lagoons), gas emissions shift in favor of **methane**.
- ❑ These findings underscore the importance of considering different **manure management practices** to effectively mitigate greenhouse gas emissions in livestock production systems.



Energy Consumption



- ❑ Energy is a crucial component in various processes within animal husbandry: fertilizer production, machinery use, and transportation of feed and livestock.
- ❑ On-farm operations require energy for heating/cooling, feeding, ventilation, lighting, milking, and manure management.
- ❑ **Electricity** is predominantly used for lighting, feeding, and milking systems
- ❑ **Fossil fuels** are commonly associated with direct energy consumption for manure management and heating.
- ❑ Both, the production of feed for livestock and the production of animal products entail **significant energy consumption**.



Funded by the
European Union



Energy Consumption

- ❑ **Fossil fuels** serve as the primary source of energy in animal husbandry, contributing to additional CO2 emissions.
- ❑ Approximately 25% of total emissions in the livestock sector are attributed to the energy consumption involved in the production cycle of animal products.
- ❑ Within this cycle, the **production of animal feed**, whether concentrates, canned feed, or pasture, is recognized as the **most energy intensive process**.
- ❑ However, there are analytical challenges regarding energy consumption in feed production, as it often occurs off-farm and is not consistently attributed to the livestock sector in official agricultural statistics.

Energy Consumption



- ❑ Feed production, storage, and transportation processes require substantial energy inputs, including fuel, fertilizers, and pesticides.
- ❑ The production of animal products tends to be energy inefficient, with a significant portion of energy expended on maintaining body structure and physiological processes, rather than on structures directly usable for human nutrition.
- ❑ Various factors influence energy consumption in livestock production, including the species and type of animals, geographical location, agro-ecological conditions, and production system.
- ❑ Overall, energy consumption in animal husbandry is concentrated in feed production, housing, and manure management, highlighting areas for potential energy-saving strategies and sustainability initiatives.



Funded by the
European Union

Energy Consumption

□ There are significant variations in energy consumption across different livestock production systems (Figure 6):

- **Milk production** ranges from 2.1 to 5.3 MJ/kg per ECM (Energy Corrected Milk).
- **Cow-calf system** production requires approx. 59.2 MJ/kg.
- **Pork production** ranges from 15.9 to 22.7 MJ/kg.
- **Broiler production** consumes between 9.6 and 19.1 MJ/kg.
- **Egg production** ranges from 3.5 to 20.5 MJ/kg

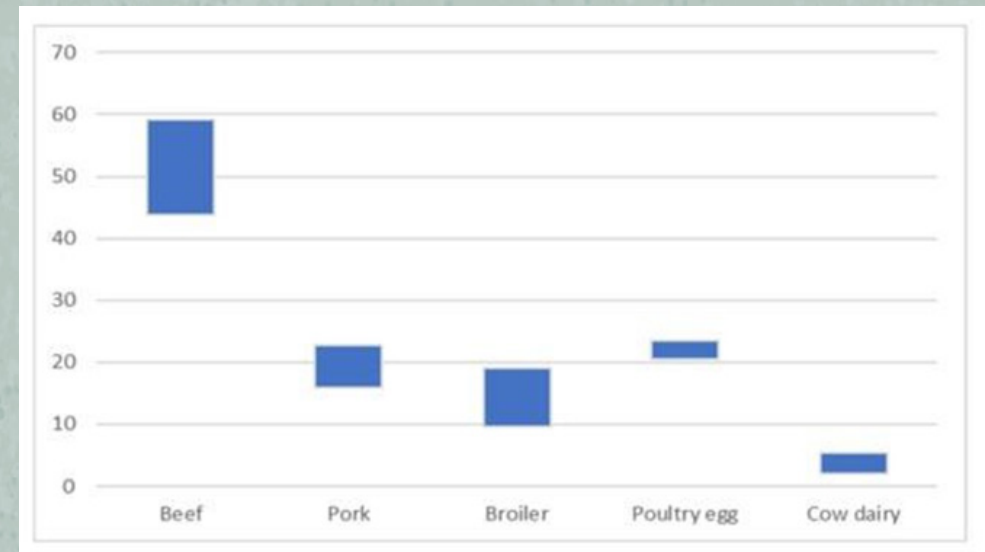


Figure 6. Energy consumption in the production of animal products in relation to the type of livestock (MJ/kg) [6].

Energy Consumption



Table 1. Intervals of energy inputs (low-high) for indirect (feeds) and direct consumption in different production systems (MJ/kg) [6].

Production System	Animal Feed		Direct Energy Use	
	Low	High	Low	High
Cow milk	1.11	4.4	0.54	1.76
Beef	17.34	27.23	9.36	31.97
Pork	11.6	16.41	2.6	11.1
Broiler	6.5	14.82	0.5	6.6
Egg	10.3	13.2	0.6	10.3

- ❑ **Feed production** is the dominant indirect energy input, constituting 75% of consumption across livestock systems in the EU27, except for beef production (Table 1).
- ❑ Direct energy consumption in **beef production** is primarily attributed to housing, feeding, and manure management.
- ❑ **Dairy farming's** direct energy use is largely attributed to milking, milk cooling, and water heating.
- ❑ **Cattle farming** has the **highest energy intensity** per kilogram of meat production, followed by pig and poultry farming.



Energy Consumption



- ❑ As agriculture intensifies, the livestock sector must transition to more sustainable production methods to mitigate environmental impact and reduce harmful gas emissions.
- ❑ This shift entails adopting alternative and eco-friendly production technologies rooted in ecological principles.
- ❑ Embracing renewable energy sources will be pivotal in achieving environmental sustainability within the livestock industry.
- ❑ The transition to sustainable practices in livestock production is essential for reducing greenhouse gas emissions and promoting environmental conservation.



Funded by the
European Union

Sources



[1] Gerber, P. J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A., & Tempio, G. (2013). Tackling climate change through livestock: A global assessment of emissions and mitigation opportunities. *Tackling Climate Change through Livestock: A Global Assessment of Emissions and Mitigation Opportunities*.

<https://www.cabdirect.org/cabdirect/abstract/20133417883>

[2] Dashboardold | Global Livestock Environmental Assessment Model (GLEAM) | Food and Agriculture Organization of the United Nations. (n.d.). Retrieved 24 March 2023, from <https://www.fao.org/gleam/results/en/>

<https://doi.org/10.1093/af/vfy034>

[3] Zhao, Y., Nan, X., Yang, L., Zheng, S., Jiang, L., & Xiong, B. (2020). A Review of Enteric Methane Emission Measurement Techniques in Ruminants. *Animals*, 10(6), Article 6.

<https://doi.org/10.3390/ani10061004>

[4] Liu, G. (2012). *Greenhouse Gases: Capturing, Utilization and Reduction*. BoD Books on Demand.

[5] [Grossi, G., Goglio, P., Vitali, A., & Williams, A. G. \(2019\). Livestock and climate change: Impact of livestock on climate and mitigation strategies. *Animal Frontiers*, 9\(1\), 69–76.](https://doi.org/10.1093/af/vfy034)

<https://doi.org/10.1093/af/vfy034>

[6] Paris, B., Vadorou, F., Tyris, D., Balafoutis, A. T., Vaiopoulos, K., Kyriakarakos, G., Manolakos, D., & Papadakis, G. (2022). Energy Use in the EU Livestock Sector: A Review Recommending Energy Efficiency Measures and Renewable Energy Sources Adoption. *Applied Sciences*, 12(4), Article 4.

<https://doi.org/10.3390/app12042142>



USV 1842



Funded by the
European Union



Funded by the
European Union



INDIRECT EFFECTS OF LIVESTOCK PRODUCTION ON GHG EMISSIONS

FEED PRODUCTION AND LAND USE CHANGE

Dr. Dušica Ostojić Andrić

Introduction



- ❑ The production of animal feed generates the largest amounts of CO_2 , which originate from the production of fertilizers, pesticides and transport.
- ❑ NO_2 emissions arise from the use of fertilizers, manure and the cultivation of forage legumes.
- ❑ Emissions of CH_4 in animal feed production are significantly lower compared to CO_2 and N_2O .
- ❑ Animal feed production often leads to changes in land use such as deforestation, which further impacts climate change.
- ❑ About 50% of N_2O and CH_4 emissions come from the fertilization of forage crops and the application of manure on pastures.
- ❑ A quarter of the total emissions are related to changes in land use.



USV 1842



Funded by the
European Union

Feed Production



- ☐ GHG emissions caused by the production, processing and transport of animal feed make up about **45% of the total emissions** from animal husbandry.
- ☐ Feed production in poultry and pig farming contributes 60-80% of GHG emissions, while in cattle breeding, this share is 35-45 %.
- ☐ The production of fodder is a complex process consisting of different technological stages.
- ☐ At each stage of the animal feed production process, a certain amount of harmful gases is emitted.
- ☐ Different agro-ecological conditions and animal feeding and rearing technologies significantly affect the size of the emission in different regions and at the local level.
- ☐ Models for estimating emissions from animal feed production require the inclusion of a large number of factors and extensive information for analysis.



Feed Production

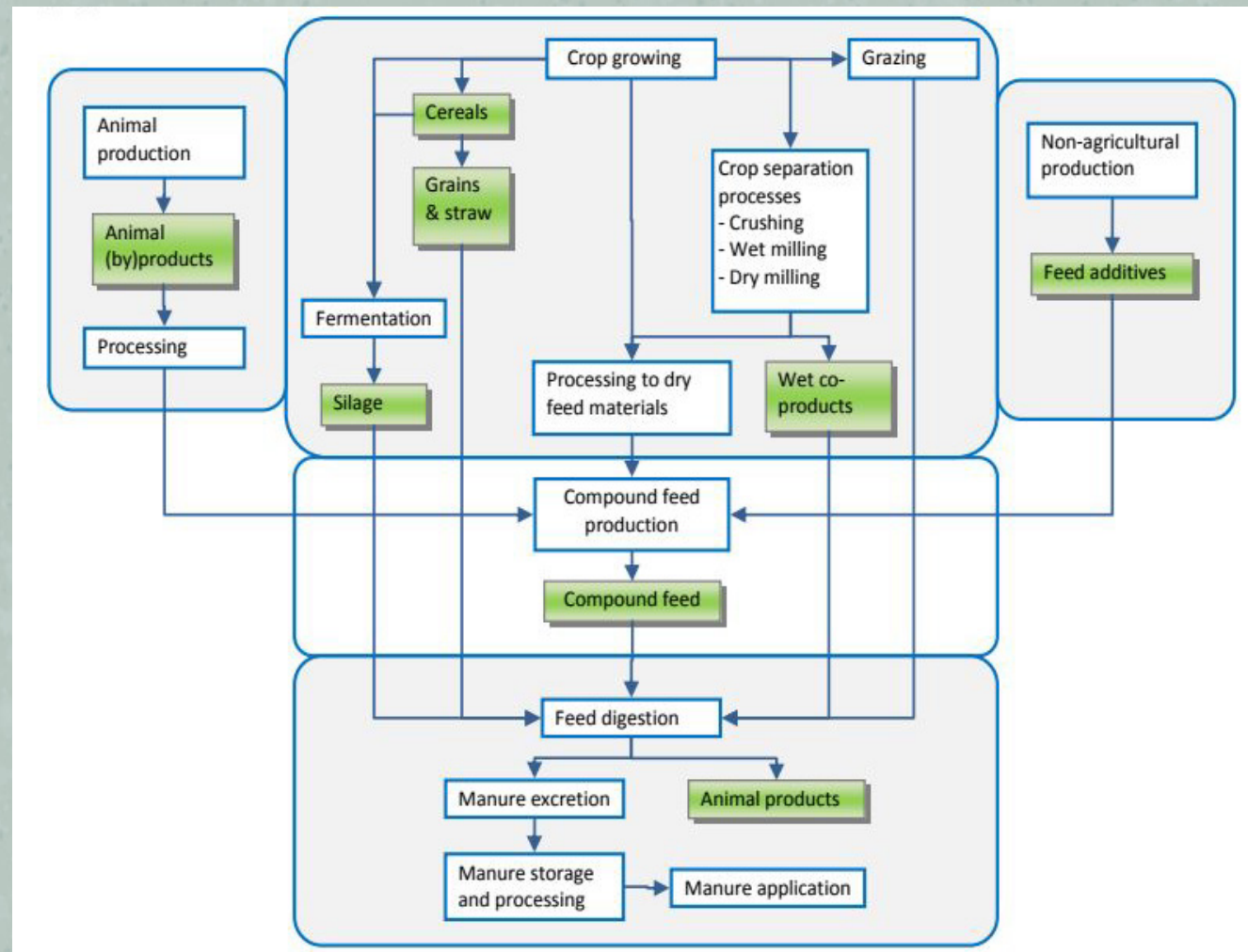


Figure 1. Diagram of the entire process of production and use of animal feed (green fields represent animal feed) [1]



Funded by the
European Union



Feed Production

- ❑ The variety of fodder is great.
- ❑ **Pastures** are used at the place of production, so there are no emissions from the storage and transportation process.
- ❑ **Canned feedstuffs** (silage and hay) require storage and often processing, which increases the level of emissions during their production.
- ❑ The production of **feed mixtures** requires industrial processing and each component requires certain inputs and energy, which affects the emission of GHG.
- ❑ **Storage and transportation** are additional factors that affect emissions, and occur at every stage of production.
- ❑ In the production chain, we distinguish between inputs, activities and side effects, which are characterized by certain emission characteristics.
- ❑ **Total emission** is the result of used inputs and activities

Feed Production



❑ In most cases **the total emission is the resultant** emissions generated in the following **processes** food production :

- Growing crops
- Transportation
- Storage
- Fertilization
- Use of machinery
- Use of pesticides
- Industrial processing
- Use of fossil fuels and electricity
- Other

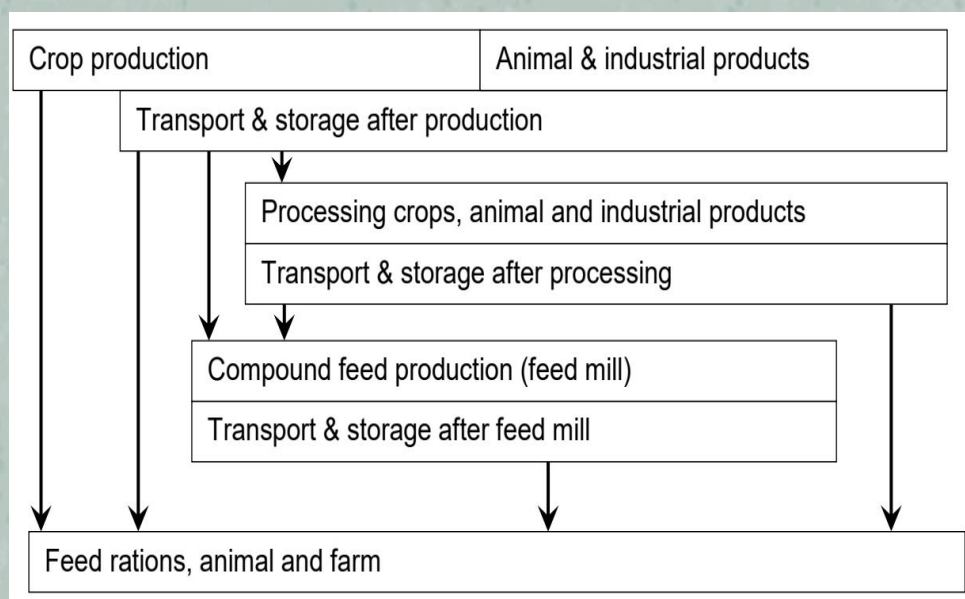


Figure 2. Relationships between procedures in animal feed production [2]



Funded by the
European Union



Feed Production

- ❑ **Crop production** involves various stages and activities - from seed material to processing and use in feed mixtures.
- ❑ **The use of inputs** such as fertilizers, pesticides and fuels generates GHG emissions at various stages of crop production.
- ❑ Some inputs, such as **nitrogen fertilizers and fuels**, cause GHG emissions during the consumption phase, while pesticides, phosphate or potassium fertilizers e.g. do not cause emissions at this stage.
- ❑ **The use of machinery** for plowing and fertilizing requires energy consumption and generates associated GHG emissions.
- ❑ **Estimates of GHG emissions** for different forms of animal feed are shown in Table 1.



Feed Production

Table 1. Estimated GHG emissions in the production of grasses, corn and alfalfa (in grams of CO₂ - eq per kg of product) [2].

Nutritious	Grass, fresh	Grass, silage	Grass, dry	Corn, silage	Corn, dry	Alfalfa, fresh	Alfalfa, silage	Alfalfa, dry
DM content (g/kg)	163	474	918	301	909	200	403	910
GHG emission (gCO ₂ -eq / kg)								
Cultivation	87	240	201	49	49	68	149	68
Transport to processing			35		35			35
Allocation factor			3.39		3.39			3.39
From cultivation (including allocation)			682		166			231
Processing (drying)	0	0	1168	0	1157	0	0	1168
Total for cultivation, processing and transport (sum of the previous ones)			in 1885		1358			1434
Transport to the animal feed factory								
Animal feed factory								
Finalization at the factory								
Transport to the farm	0	0	10	0	10	10	10	10



USV 1842



Funded by the
European Union



Feed Production

- ❑ The carbon footprint of animal feed is subject to variation due to various factors, including type of feed, production methods and geographic location.
- ❑ Foods that require more nitrogen fertilizers have a larger carbon footprint (corn , soybeans and wheat).
- ❑ Nitrogen fertilizers require large amounts of energy to produce and can release nitrous oxide, a powerful greenhouse gas.
- ❑ Production and transport of nitrogen fertilizers contribute to GHG emissions which further affects the carbon footprint.
- ❑ GHG emissions per ton of nitrogen fertilizers vary worldwide, and application of phosphorus and potassium has no effect on emissions.

Feed Production

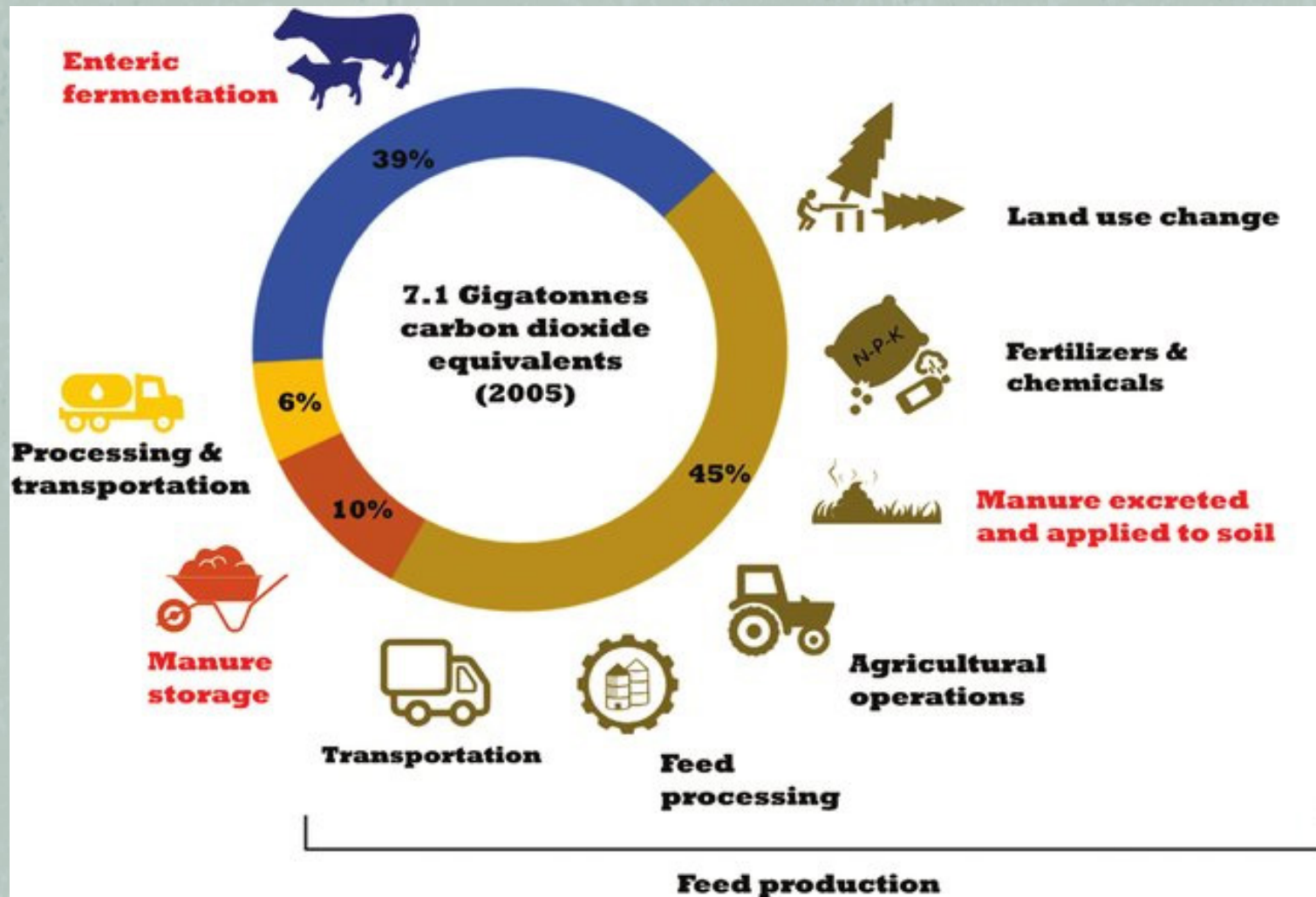


Figure 3. Contributions of emissions from different processes in the production of animal feed and direct emissions (red text) [3;4].



Funded by the
European Union



Feed Production

- ☐ **Manure** is an important source of organic matter for the soil, but its use can cause significant emissions of nitrogen oxides, which make up about half of the total emissions.
- ☐ When manure is used in large quantities, it can have negative side effects in the form of high nitrogen content, which can cause **eutrophication and acidification**.
- ☐ When raising animals **on pastures**, their excrement is deposited in the soil which contributes to GHG emissions.
- ☐ Applying manure to lawns or arable land can reduce the use of synthetic fertilizers, which should reduce GHG emissions from synthetic fertilizer production.
- ☐ Good manure management can contribute to reducing the need for artificial fertilizers.

Feed Production



- ❑ **Transporting animal feed** over long distances generates greenhouse gas emissions (CO₂ and nitrogen oxides) from trucks, ships and other vehicles.
- ❑ In the production **of beef**, the contribution **of transport** to the total emission of greenhouse gases is **less than 4%**, and for **pork** it is **16 %**.
- ❑ Emissions from fossil fuels and electricity mainly come from transport and machinery.
- ❑ **The electricity used** to produce animal feed comes from a variety of sources, including fossil fuels, nuclear and hydropower, and the efficiency of its production varies depending on the technology used.





Feed Production

- ❑ **Industrial feed processing** can have a significant impact on GHG emissions, both directly and indirectly.
- ❑ **The direct impact** refers mainly to the consumption of electricity and fossil fuels in the use of machines and mechanization in production processes, as well as the transport of inputs and nutrients.
- ❑ **Indirect influence** is e.g. the one that the use of industrially processed animal feed can have on **the properties of manure**. Namely, **the richer nutrient composition** of such feeds is also reflected in the characteristics of manure, which can result in **increased emissions of CH₄ and N₂O**.
- ❑ It can be concluded that within the sector of animal feed production, the phase of its industrial processing represents an important area in efforts to reduce the carbon footprint.



Funded by the
European Union



Land Use Change

- ❑ **Agricultural land** makes up about **40%** of the world's land surface.
- ❑ About **60%** of that area **is used for feeding livestock**.
- ❑ Projected human population growth predicts an increase in demand for animal products.
- ❑ This will lead to the need for a larger area for the cultivation of plant crops that are used in livestock nutrition.
- ❑ The intensification of agriculture and animal husbandry is taking place at an accelerated pace.
- ❑ **Changing the use of land**, such as converting forests into arable land, has a negative impact on the climate.
- ❑ The release of carbon dioxide into the atmosphere and the inability to absorb and store carbon disrupts **the carbon cycle** (Figure 4).
- ❑ Accelerated industrialization contributes to the devastating impact on the environment, especially in terms of climate change.

Land Use Change

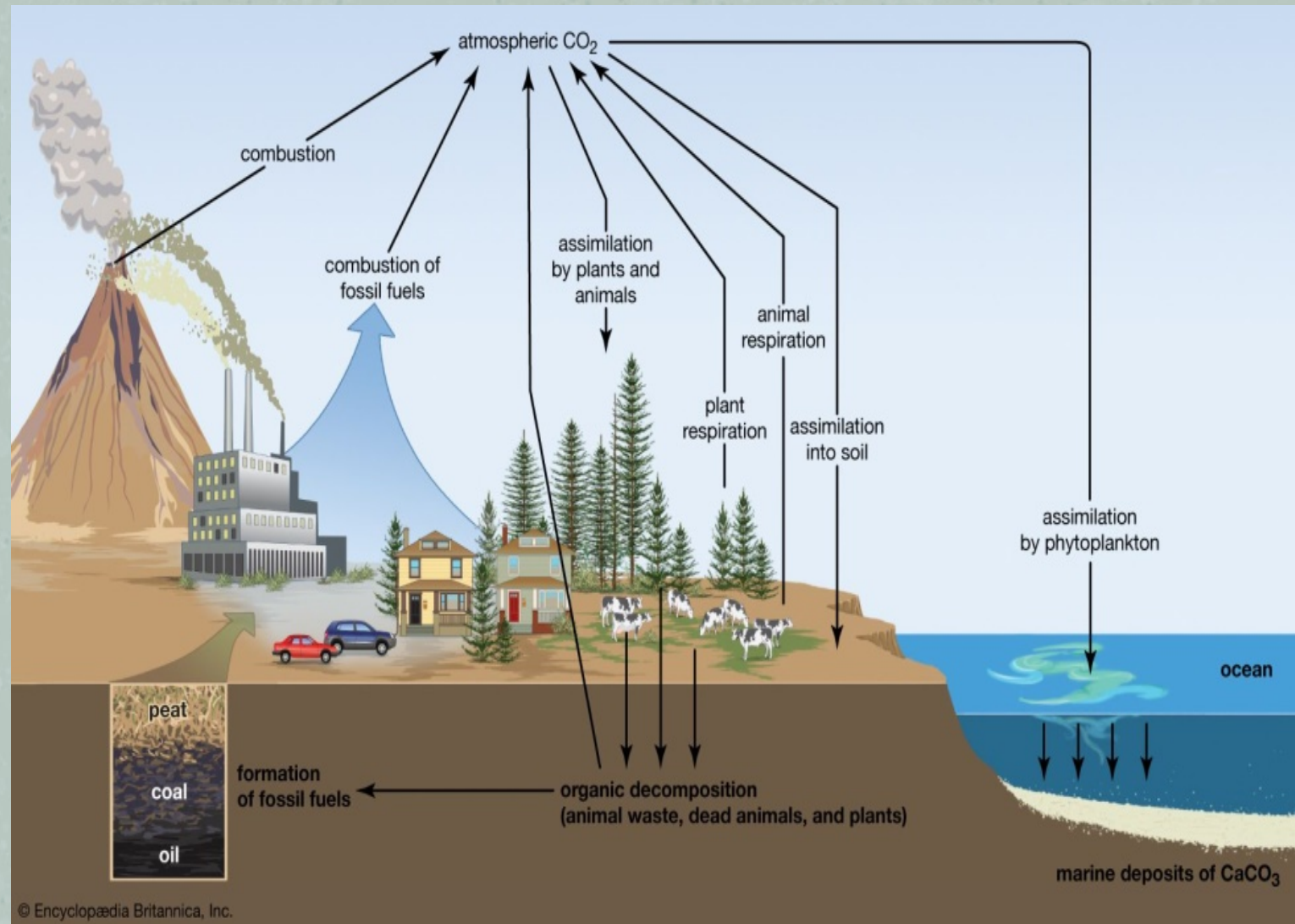


Figure 4. Carbon cycle [5]



Funded by the
European Union



Land Use Change

- ❑ Through **photosynthesis**, plants absorb carbon dioxide from the atmosphere and store it in biomass.
- ❑ **Forest land** has a better ability to absorb carbon than arable land and pastures.
- ❑ **The conversion** of forest to arable land and pastures results in the emission of a large part of the stored carbon into the atmosphere.
- ❑ There are several methods for estimating greenhouse gas emissions due to land use change.
- ❑ The scientific community has not yet reached an agreement regarding the reliability of those methods .
- ❑ Table 2. shows the emission values obtained by different assessment methodologies.

Land Use Change



Table 2. Values of GHG emissions due to land use change (green fields) comparison of different assessment methodologies [2]

	Wheat France	Soy Brazil	Rapeseed seeds Germany	Palm fruits Malaysia
Input of N through organic fertilizer (kg/ha)	29	41	62	27
Input of N through artificial fertilizer (kg/ha)	119	3	200	130
Yield of the main product (kg/ha)	6565	2442	3610	21300
Byproduct yield (kg/ha)	3764	0	0	0
Allocation emissions for the main product ()	0.78	1	1	1
GHG for the main product (g/kg)	337	477	1032	604
Emissions due to land change:				
FeedPrint (based on 1180 kg/ha) (g/kg)	141	483	327	55
Audsley et al. (2010) (1430 kg/ha)* (g/kg)	171	585	396	67
FAO (2010) (g/kg)	0	7690	0	
Leip et al. (2010) (g/kg)	35	1099 - 1207	153	



Land Use Change



- ❑ Land use change has already contributed significantly and negatively to climate change, but improvements are still possible.
- ❑ Important is the timely and continuous application of improved agricultural practices and activities to mitigate the impact on forests, which can significantly contribute to the removal of carbon dioxide from the atmosphere:
 - improved crop and pasture management —eg. more efficient use of fertilizers to prevent leaching of unused nitrates,
 - practices that minimize soil erosion,
 - restoration of organic soil and restoration of degraded soils.



Funded by the
European Union

Sources



[1] Blonk , TJ and Ponsioen , 2010. Towards a tool for assessing carbon footprints of animal feed. Report Blonk Milieu Advies , November 2009, Gouda, the Netherlands, 62 pp .

[2] Vellinga , TV, Blonk , H., Marinussen , M., Zeist, WJ van, & Starman , D. a. J. (2013). Methodology used in FeedPrint : A tool quantifying greenhouse gas emissions of feed production and utilization (No. 674; p. 121). Wageningen UR Livestock Research.

<https://library.wur.nl/WebQuery/wurpubs/438366>

[3] Gerber , PJ, Steinfeld , H., Henderson, B., Mottet , A., Opio , C., Dijkman , J., Falcucci , A., & Tempio , G. (2013). Tackling climate change through livestock: A global assessment of emissions and mitigation opportunities. Tackling Climate Change through Livestock: A Global Assessment of Emissions and Mitigation Opportunities.

<https://www.cabdirect.org/cabdirect/abstract/20133417883>

[4] Gerber, PJ, Hristov , AN, Henderson, B., Makkar , H., Oh, J., Lee, C., Meinen , R., Montes, F., Ott , T., Firkins, J. , Rotz , A., Dell, C., Adesogan , AT, Yang, WZ, Tricarico , JM, Kebreab , E., Waghorn , G., Dijkstra , J., & Oosting , S. (2013). Technical options for the mitigation of direct methane and nitrous oxide emissions from livestock: A review. Animal, 7(s2), 220–234. <https://doi.org/10.1017/S1751731113000876>

[5] Carbon Sequestration | Definition, Methods, & Climate Change | Britannica, 2023. Retrieved 31 March 2023, from [https:// www.britannica.com/technology/carbon-sequestration](https://www.britannica.com/technology/carbon-sequestration)



Funded by the
European Union



Funded by the
European Union



MITIGATION STRATEGIES

LAND RESOURCE MANAGEMENT, ENTERIC
FERMENTATION MANAGEMENT, AND MANURE
MANAGEMENT

Dr. Dušica Ostojić Andrić

Introduction



- ❑ Reducing GHG emissions from livestock farming is key to combating climate change and reducing associated risks, environmental degradation, protecting ecosystems and biodiversity, improving public health and economic stability, and promoting a more sustainable and just future for all.
- ❑ While adaptation efforts are also key, mitigation remains the most effective way to address the root causes of these challenges, as the livestock sector is a significant contributor to global emissions.



- ❑ A summary of mitigation strategies (excluding land management practices) is presented in Table 1.



Introduction



Table 1. Methane emission mitigation potential of the main strategies in livestock production [1].

		Potential mitigating effect*	
Strategies		Methane	Nitrous Oxide
Enteric fermentation	Forage quality		
	Feed processing	Low to medium	†
	Concentrate inclusion	Low	Low
	Dietary lipids	Low to medium	†
	Electrons receptors	Medium	†
	Ionophores	High	†
	Methanogenic inhibitors	Low	†
Manure	Solid-liquid separation	Low	†
	Anaerobic digestion	High	Low
	Decreased storage time	High	High
	Frequent manure removal	High	High
	Phase feeding	High	High
	Reduced dietary protein	‡	Low
	Nitrification inhibitors	‡	Medium
Animal management	No grazing on wet soil	‡	Medium to high
	Increased productivity	Low	Medium
	Genetic selection	High	High
	Animal health	High	‡
	Increase reproductive eff.	Low to medium	Low to medium
	Reduced animal mortality	Low to medium	Low to medium
	Housing systems	Low to medium	Low to medium
	Forage quality	Medium to high	Medium to high

*High = ≥30% mitigation effect; Medium = 10–30% mitigation effect; Low = ≤10% mitigation effect.

†Inconsistent/variable results; ‡Uncertainty due to limited research or lack of data.



Introduction



- ❑ The EU strategy entitled "carbon farming" has gained increasing importance in recent years .
- ❑ It is focused on land and livestock management through the management of carbon reserves in soil, materials and vegetation, GHG flows at the farm level, with the aim of mitigating climate change.
- ❑ "Carbon farming" includes practices and changes in land use that produce one or more of the following outcomes:
 - 1) uptake of carbon (sequestration) and its storage in biomass above/under the ground and in agricultural land;
 - 2) avoiding future emissions of CO₂ and other GHG i
 - 3) reduction of existing CO₂ and other GHG emissions .
- ❑ Livestock farming is responsible for anthropogenic GHG emissions , but at the same time it has significant potential for their mitigation.



Land Resource Management



- ❑ Management is key to **reducing the** environmental impact of livestock farming.
- ❑ Strategies that focus on land management are **more effective** than those that focus on reducing emissions from livestock.
- ❑ Switching to **more efficient animal husbandry systems** can **significantly reduce** GHG emissions .
- ❑ Breeding of cattle in feedlots e.g. generates less emissions than pasture systems.
- ❑ By applying adequate **measures in the management of pastures** and livestock production, it is possible to contribute **to a 7% reduction** in the impact of agriculture by 2030.
- ❑ Strategies include **regenerative agriculture practices** and **carbon farming**.
- ❑ The practices are based on **carbon sequestration** as a fundamental principle.



Land Resource Management

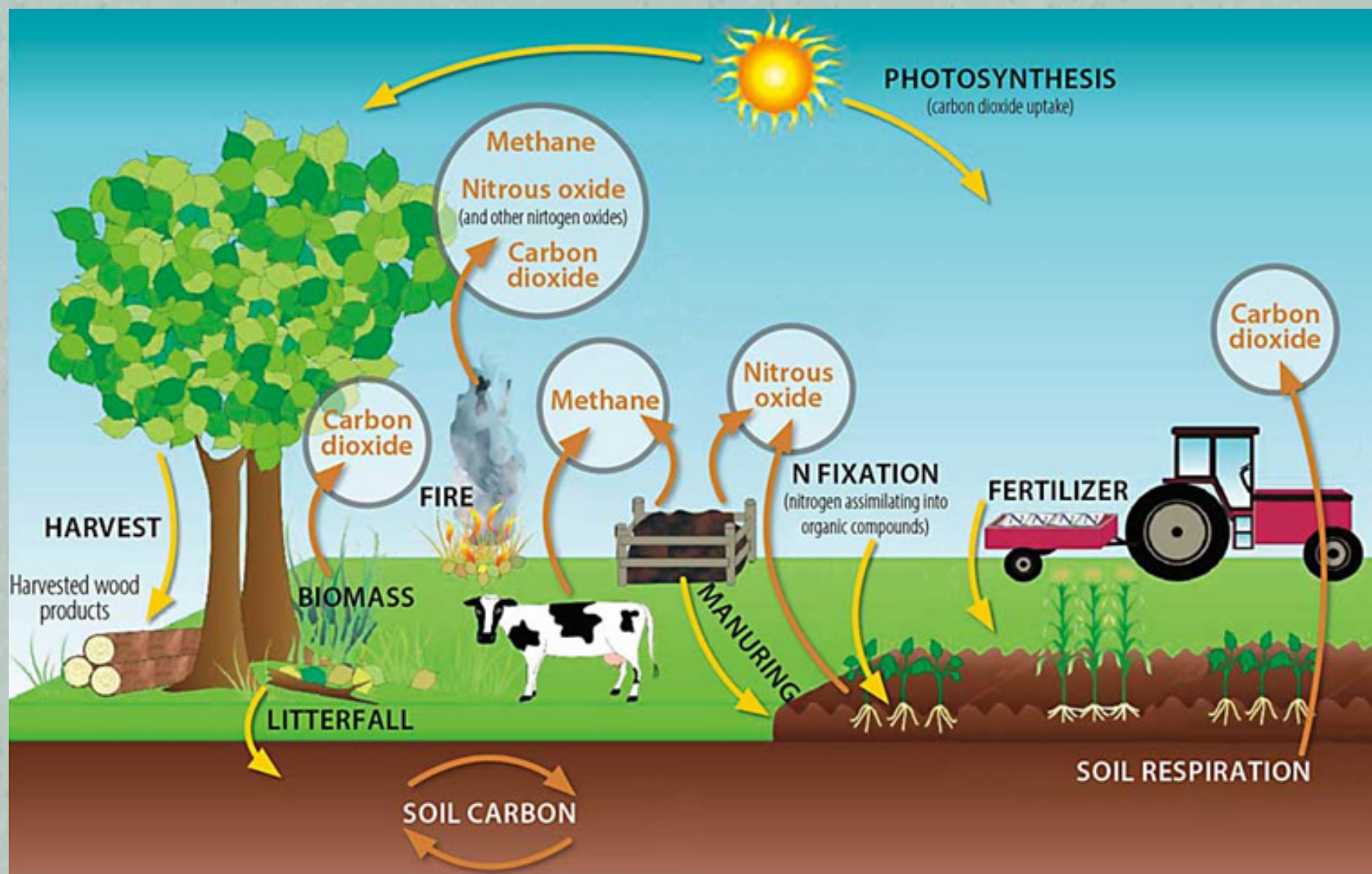


Figure 1: Main source and GHG and ways of their removal in agricultural land management [2].

Land Resource Management

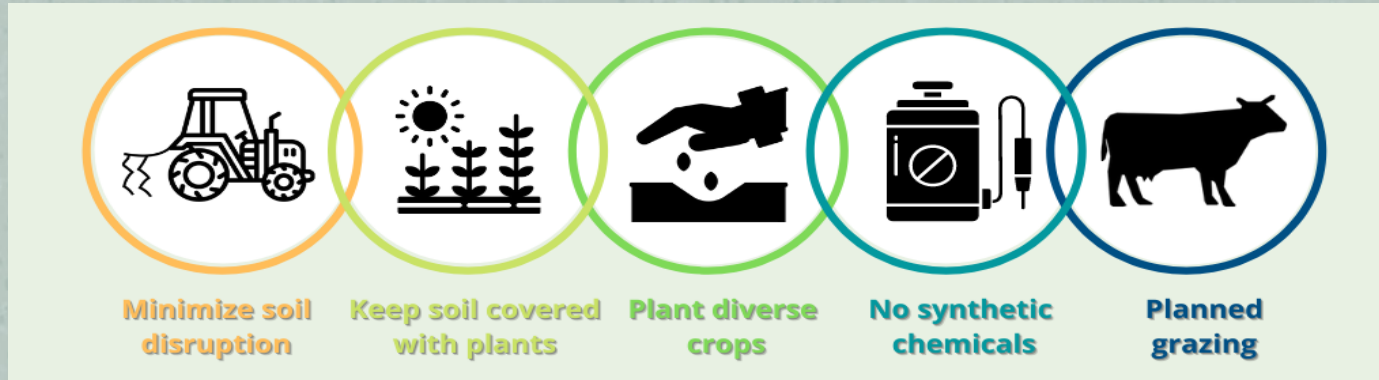


Figure 2. The Five Principles of Regenerative Agriculture, retrieved from: <https://www.soilfertilityservices.co.uk/post/the-new-word-in-farming-regenerative-agriculture>

- ❑ **Carbon sequestration** is the process of "capturing" carbon dioxide from the atmosphere and storing it in the ground.
- ❑ Land under crops and pastures can store up to 8.6 gigatons of carbon dioxide per year.
- ❑ **Improvements in the management and utilization** of agricultural land, they result in efficient sequestration of carbon in the soil, so they can mitigate the impact of livestock systems on the environment.
- ❑ By applying different **agricultural practices** commonly referred to as "**regenerative agriculture**" and "**carbon farming**" it is possible to create new or increase existing carbon sinks:

Land Resource Management



- **Regenerative agriculture** and **carbon farming** can create new or increase existing carbon sinks.
- Practices to increase productivity: fertilization , irrigation, use of productive perennial species of grasses and legumes .
- Producing **highly productive crops** reduces the need for additional land and helps protect forests and grasslands.
- Converting arable land into grasslands and **improving the floristic composition** of grasslands contributes to sequestration
- **Conservation tillage** reduces soil degradation and prevents excessive release of C into the atmosphere.
- Applying practices used in organic and sustainable agriculture is also important.
- **Reducing deforestation** is essential for C sequestration and ecological balance.
- Application of "**silvopasture**" as a form of agroforestry can reduce methane emissions in ruminants .



Land Resource Management



- Application of **regenerative agriculture** measures, such as **adding compost**, can further improve C sequestration in pastures.
- Sustainable management of **agricultural residues** can increase the carbon sink through the decomposition of plant residues in the soil.
- Using residual **biomass** to produce **bioenergy** instead of fossil fuel can also reduce GHG emissions.

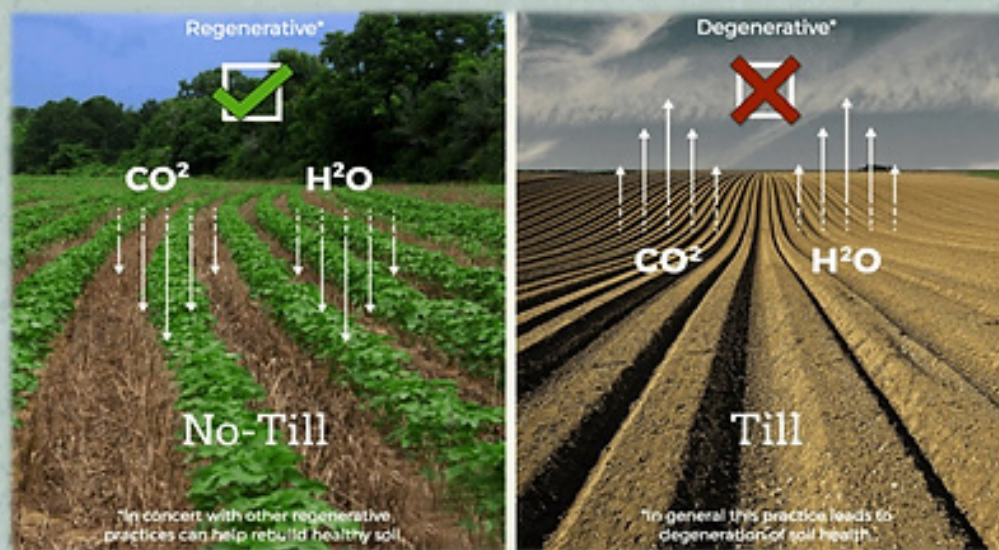


Figure 3. A comparison of regenerative and degenerative farming practices, retrieved from <https://www.soilfertilityservices.co.uk/post/the-new-word-in-farming-regenerative-agriculture>

Land Resource Management

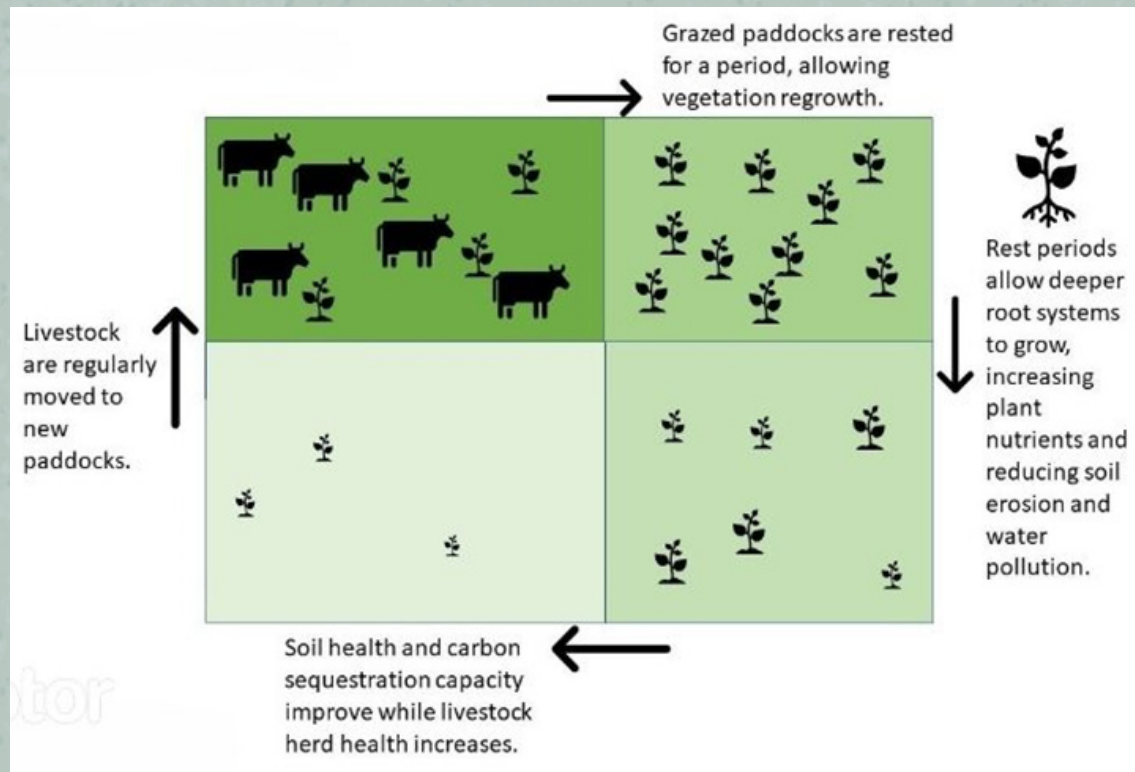


Figure 4. Advantages of the rotational grazing system [3].

- The application of **the rotational grazing system** contributes to preserving the quality of pastures and increasing productivity.
- By improving pasture management, about 0.15 Gt CO₂-eq can be deposited annually globally.

- **Rotational grazing** enables greater accumulation of organic matter (carbon) in the soil.

Enteric fermentation



- ❑ Reducing methane emissions in **ruminants** is a significant challenge in animal husbandry.
- ❑ **Strategies** for solving this problem can be divided into four categories:
 - 1) Dietary manipulation
 - 2) Feed supplements (additives)
 - 3) Vaccines and
 - 4) Genetic selection.
- ❑ These options have different levels of effectiveness in reducing methane emissions, as shown in Table 1.
- ❑ The focus is on **improving rumen fermentation efficiency** and **increasing animal productivity** to reduce methane emissions.



Enteric fermentation

1) Dietary manipulation



☐ **Quality and digestibility of animal feed** have a significant impact on methane production:

- Harvesting of forage plants at **an earlier stage of maturity** for silage, increases the content of soluble carbohydrates and **reduces lignification**.
- **Physical processing feeds** -chopping, grinding and steaming, improves digestibility

☐ **Increasing the proportion of concentrated nutrients** in the rations of ruminants improves the digestibility of the rations

- At the share of conc. nutrients of 35-40 %, methane emissions are reduced by as much as 15% per unit of km.
- The optimal ratio is important because the increase in the proportion of conc. nutrients increases the risk of developing metabolic diseases (acidosis of the rumen).



Enteric fermentation

1) Dietary manipulation

- Adding fat or fatty acids to ruminant diets can reduce intestinal methane emissions (cottonseed, cold-pressed canola).

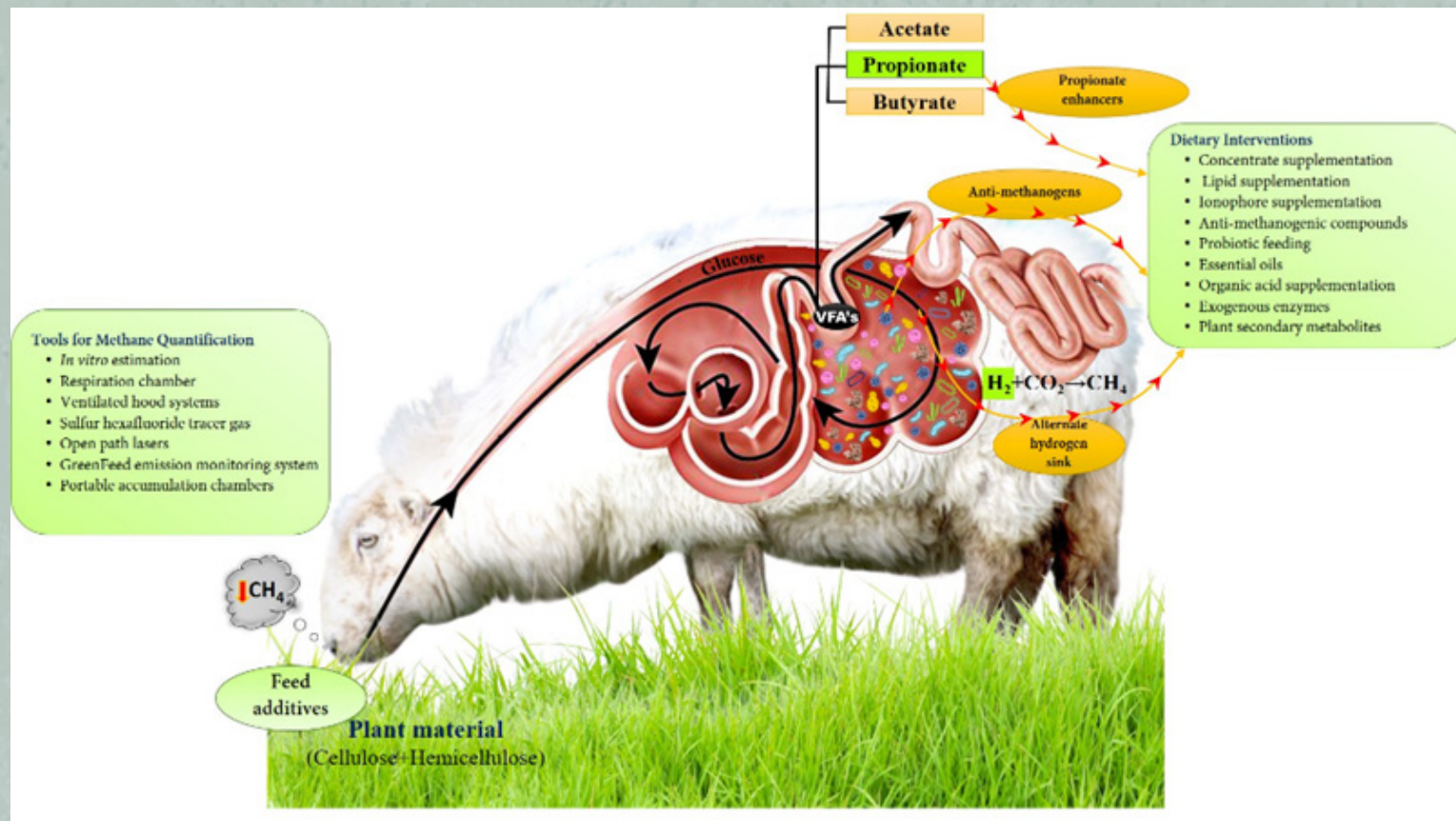


Figure 5. Dietary manipulation methods and their mode of action to reduce emissions [4].

Enteric fermentation

2) Additives

- modify the biochemical processes of the rumen in the direction of suppression of methanogenesis:

- Essential oils
- Seaweed
- Organic acids
- Ionophores
- Probiotics
- Secondary metabolites from medicinal and aromatic plants

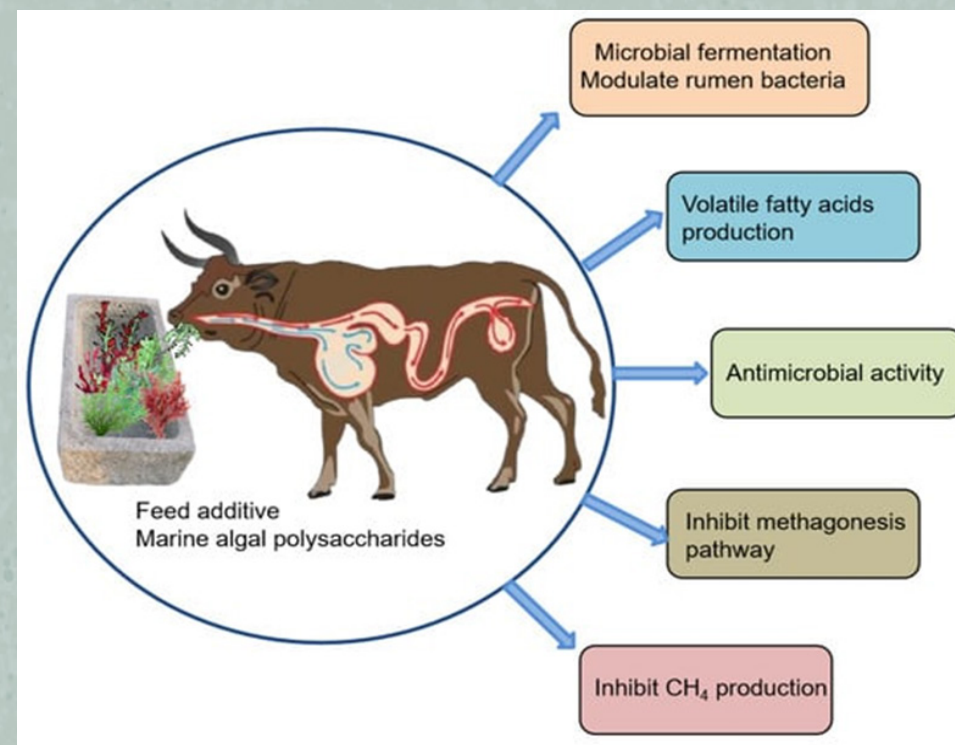


Figure 6. Seaweed polysaccharides as food additives that reduce methane emissions [5].

- despite its effectiveness, more extensive research is needed to rule out side effects (toxicity and associated health risks)

Enteric fermentation

3) Vaccines

- trigger an immune response and the creation of antibodies - a suppressive effect on **the activity of methanogens** in the rumen .

- administration of the first vaccines is not expected before 2030 .

4) Genetic selection

- selection and favoring of individuals with a desirable genetic code in terms of reduced methane production and emissions.

- long-term efficient

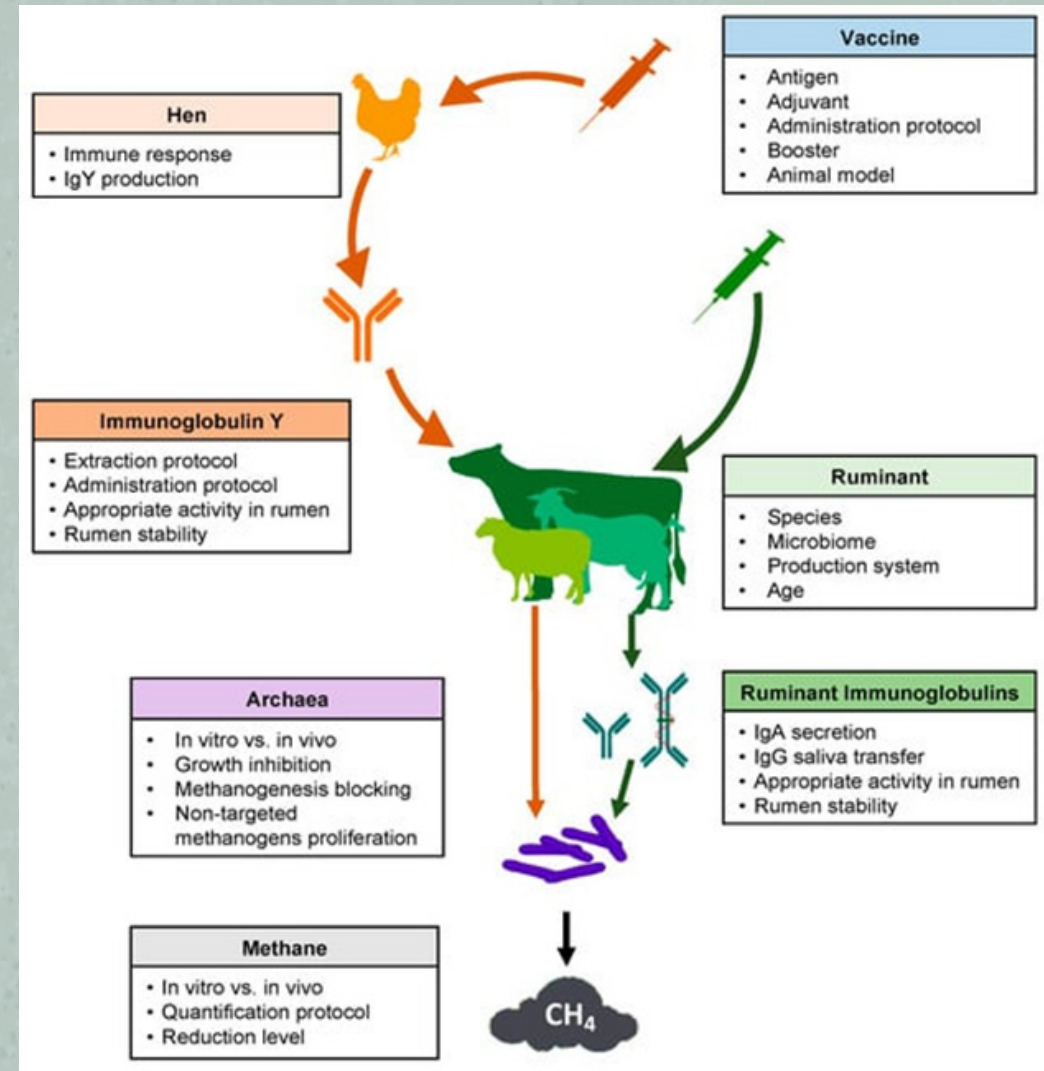


Figure 7. Key considerations for methane-reducing vaccines in ruminants [6].

Manure Management



- ❑ Manure contributes to GHG emissions because its **decomposition** leads to the release of **methane and nitrous oxide**.
- ❑ **The level of emission** depends on environmental conditions, management methods and the composition of organic matter and nitrogen content in excreta.
- ❑ **Methane** is produced when organic matter in anaerobic conditions is incompletely decomposed under the influence of bacteria.
 - most often when **liquid manure is** stored or treated in lagoons (promoted by long storage, warm and humid environmental conditions).
- ❑ **Nitrogen oxide** is produced mostly from **solid manure**, its storage or deposition on pastures in a combination of aerobic and anaerobic conditions.



Funded by the
European Union

Manure Management



- ❑ GHG emissions are higher in solid manure systems.
- ❑ The most important practices to reduce emissions from manure are:
 - **Dietary manipulation:**
 - The effect of a protein- balanced diet on denitrification and N₂O emission (reduction of N excretion through excreta)
 - Enriching meals with tannin
 - **Manipulation of storage temperature:** cooling of manure to reduce methanogenesis.
 - **Composting of solid manure:** aerobic decomposition under the influence of microorganisms (turning and aeration further enhance the effect).
 - **Covering manure:** reduction of NH₃, N₂O and CH₄ emissions .



Manure Management



- **Manure separation:** separation of liquid and solid parts for more efficient processing of each phase.
- **Anaerobic digestion:** double effect - production of biogas and reduction of CH₄ emissions.
- **Manure aeration:** reduction of total GHG emissions with a possible increase in N₂O emissions.
- **Treatment with additives:** changing the chemical properties of manure, pH values, most often - acidification of the substrate to reduce GHG emissions.

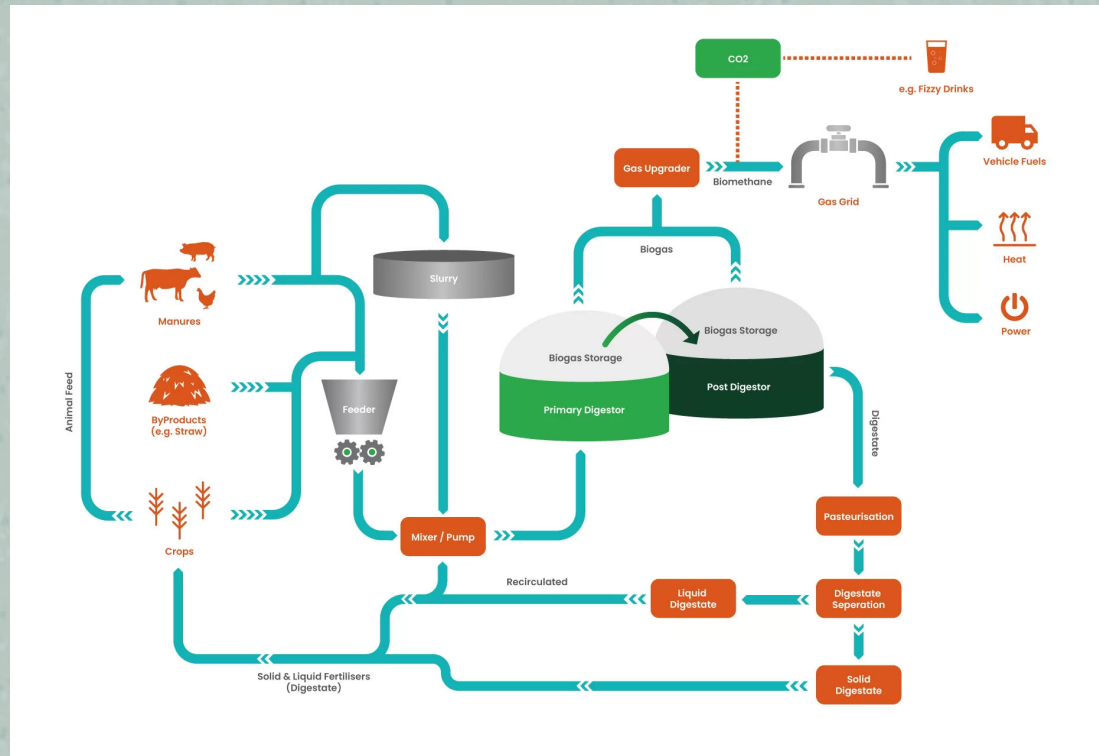


Figure 8. Anaerobic digestion technology, retrieved from <https://www.dealfarmbiogas.co.uk/process/>

Sources



[1] Grossi, G., Goglio, P., Vitali, A., & Williams, A. G. (2019). Livestock and climate change: Impact of livestock on climate and mitigation strategies. *Animal Frontiers*, 9(1), 69–76.

[2] Intergovernmental Panel on Climate Change (IPCC). (2019). *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*, edited by P. R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, and J. Malley.

[3] USDA Northwest Climate Hub. Available at <https://www.climatehubs.usda.gov/hubs/international/topic/rotational-grazing-climate-resilience>

[4] Prathap, P., Chauhan, S. S., Leury, B. J., Cottrell, J. J., & Dunshea, F. R. (2021). Towards Sustainable Livestock Production: Estimation of Methane Emissions and Dietary Interventions for Mitigation. *Sustainability*, 13(11), Article 11.

[5] Cheong, K.-L., Zhang, Y., Li, Z., Li, T., Ou, Y., Shen, J., Zhong, S., & Tan, K. (2023). Role of Polysaccharides from Marine Seaweed as Feed Additives for Methane Mitigation in Ruminants: A Critical Review. *Polymers*, 15(15), Article 15.

[6] Baca-González, V., Asensio-Calavia, P., González-Acosta, S., Pérez de la Lastra, J. M., & Morales de la Nuez, A. (2020). Are Vaccines the Solution for Methane Emissions from Ruminants? A Systematic Review. *Vaccines*, 8(3), Article 3.





USV 1842



Funded by the
European Union



ANIMAL ADAPTATION STRATEGIES - ANIMAL RESPONSES

PHYSIOLOGICAL, BIOCHEMICAL, IMMUNOLOGICAL,
ANATOMICAL, AND BEHAVIORAL

Dr. Dušica Ostojić Andrić

Introduction

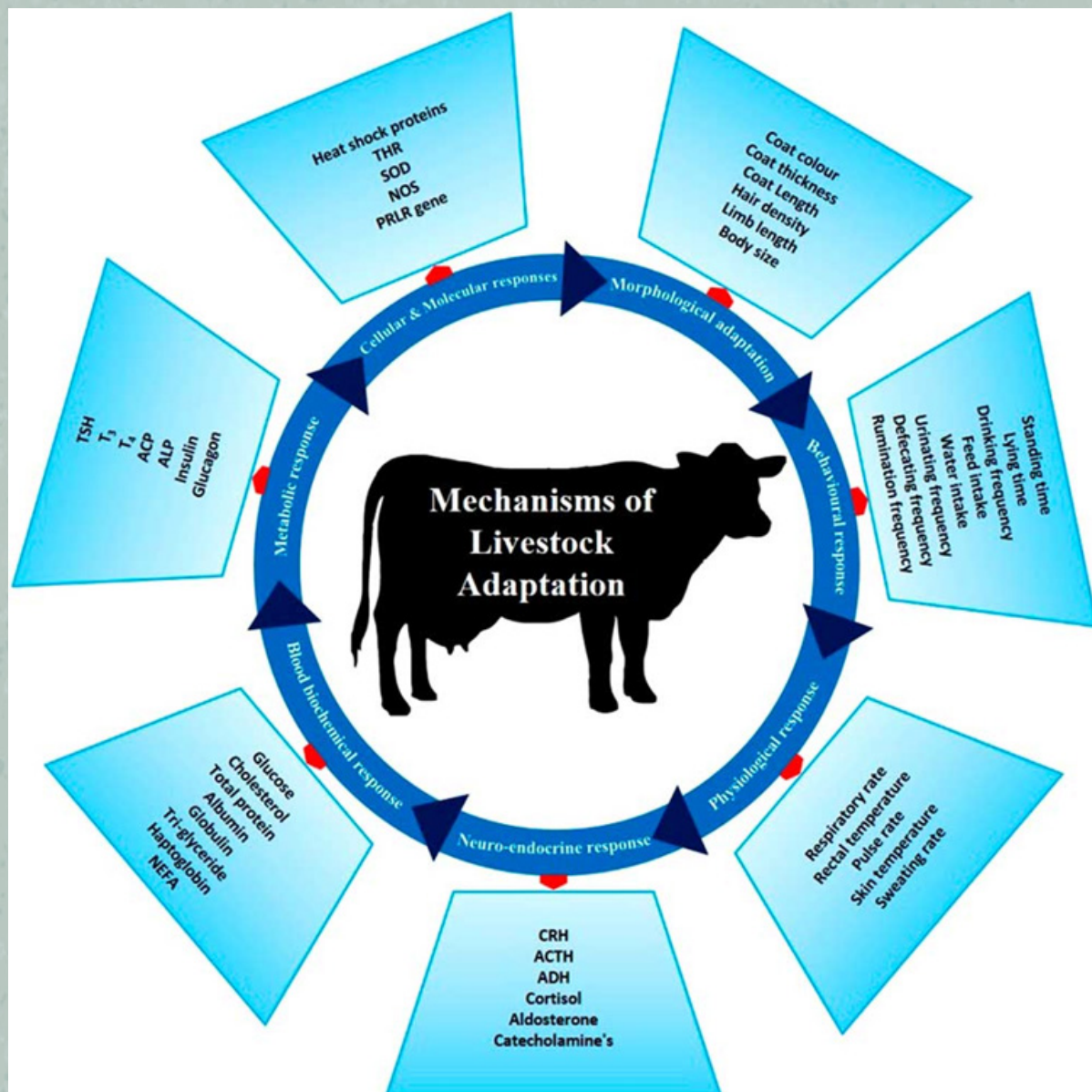


- ❑ Adapting animal husbandry to climate change requires two basic types of measures: **animal and human** .
- ❑ Animals adapt to climate conditions through various **adaptive mechanisms**, while **humans apply practices** that help them in that process.
- ❑ The effects of climate change on animal husbandry are diverse, and **heat stress** is considered the biggest challenge for farm animals
- ❑ Farm animals are often exposed **to combined stressors** such as :
 - heat stress,
 - insufficient nutrition and
 - lack of water.
- ❑ The combined impact of multiple stressors can significantly affect livestock productivity .



Funded by the
European Union

Introduction



❑ Animals have innate abilities to resist the risks of climate change through the process of **adaptation**.

❑ The **answer** animal to environmental stressors includes two phases:

- **initial** response to change i
- **later** a process that regulates **the endocrine system**.

Figure 1. Adaptive strategies of domestic animals in response to climate change [1].

Introduction



- ❑ The resulting changes aim to reduce the impact of stress, restore **homeostasis** and enable the animal to function more efficiently in a challenging environment.
- ❑ If stressful conditions persist, these changes can become **fixed genetic adaptations**.
- ❑ In the fight against climate change, the resilience and adaptability of domestic animals reflect the link between evolution and survival.
- ❑ **Responses** to various stressors may include behavioral, physiological, biochemical, immunological, anatomical or combined factors.
- ❑ These responses **can vary** depending on a variety of factors, including prior exposure to stressors, duration and intensity of stress, physiological state, and environmental constraints.



Funded by the
European Union

Introduction



- ❑ There are **significant differences in heat tolerance** between different species of animals, but also within the same species between races.
- ❑ **Polygastric animals** usually show **higher** heat tolerance than **monogastric** animals, although there is overlap in the range of environmental parameters for different species and breeds.
- ❑ **The ability to regulate** body temperature depends on a variety of interactions between anatomical and physiological factors.
- ❑ **Various characteristics**, such as skin and hair properties, sweating, breathing, tissue insulation and other factors, affect **heat load**, and the mechanisms of regulation of this load are still not fully elucidated.



Funded by the
European Union

Physiological strategies



□ are animal responses to climate change through changes in body functions, metabolism and endocrine system, with the aim of maintaining homeostasis and survival:

- Through the mechanisms of body temperature regulation by **panting and sweating** - animals dissipate excess heat by evaporating moisture into the environment .
 - **Swine** lack sweat glands and have smaller lungs relative to their body size, which reduces their ability to cool themselves by panting. This increases their thermo-sensitivity and the importance of releasing heat through the skin.
 - **Increased pulse rate** - improves circulation and redistributes blood to the skin, which enables more efficient removal of heat to the outside environment.
- **Increased rectal temperature** contributes to the release of excess heat
- **Regulation of kidney function** to better maintain proper hydration levels.



Funded by the
European Union

Physiological strategies



- The **endocrine response** plays a key role in the physiological response to heat stress by regulating the activity of the pituitary and thyroid axis during heat stress.
 - **increased cortisol production** helps animals meet additional energy needs by utilizing **gluconeogenesis** in the liver.
 - the **production of thyroid hormones** in lactating cows **decreases** to reduce the additional heat load.
- **Goats** are known for their ability to **reduce their metabolic rate** and enter a state **of torpor** during periods of extreme temperatures, which helps them conserve energy and survive harsh conditions.



Funded by the
European Union

Biochemical strategies



- ❑ In heat stress, animals exhibit biochemical changes that help them adapt and maintain homeostasis.
- ❑ The two main biochemical strategies are:
 - 1) hematological response
 - 2) cellular-molecular response

Hematological response

changes in biochemical blood parameters:

- decrease in the number of erythrocytes and hemoglobin as a result of increased oxygen consumption.
- reduction in the volume of compacted blood cells due to excess water in the circulation, necessary for heat dissipation.
- an increase in plasma albumin as a result of its antioxidant effect.
- lower glucose level due to reduced gluconeogenesis,
- decrease in the level of non-esterified fatty acids in the plasma due to higher energy consumption.



Biochemical strategies



Cellular-molecular response

Under the influence of heat stress, gene networks in cells activate mechanisms that allow cells to adapt:

- The production of heat shock protein (HSP) plays a key role in protecting cells from damage caused by heat and in maintaining cellular stability.
- Cells reduce DNA synthesis, transcription and translation, modify protein activity and stimulate HSP production .

Identification of genes related to HSP synthesis can serve as an indicator of animal adaptation to heat stress and can be used in breeding programs to create heat-resistant animals.



Funded by the
European Union

Immunological strategies



□ Climate change and heat stress affect animal health through:

- greater frequency of vector-borne diseases,
- suppression of immunity and
- inadequate nutrition.

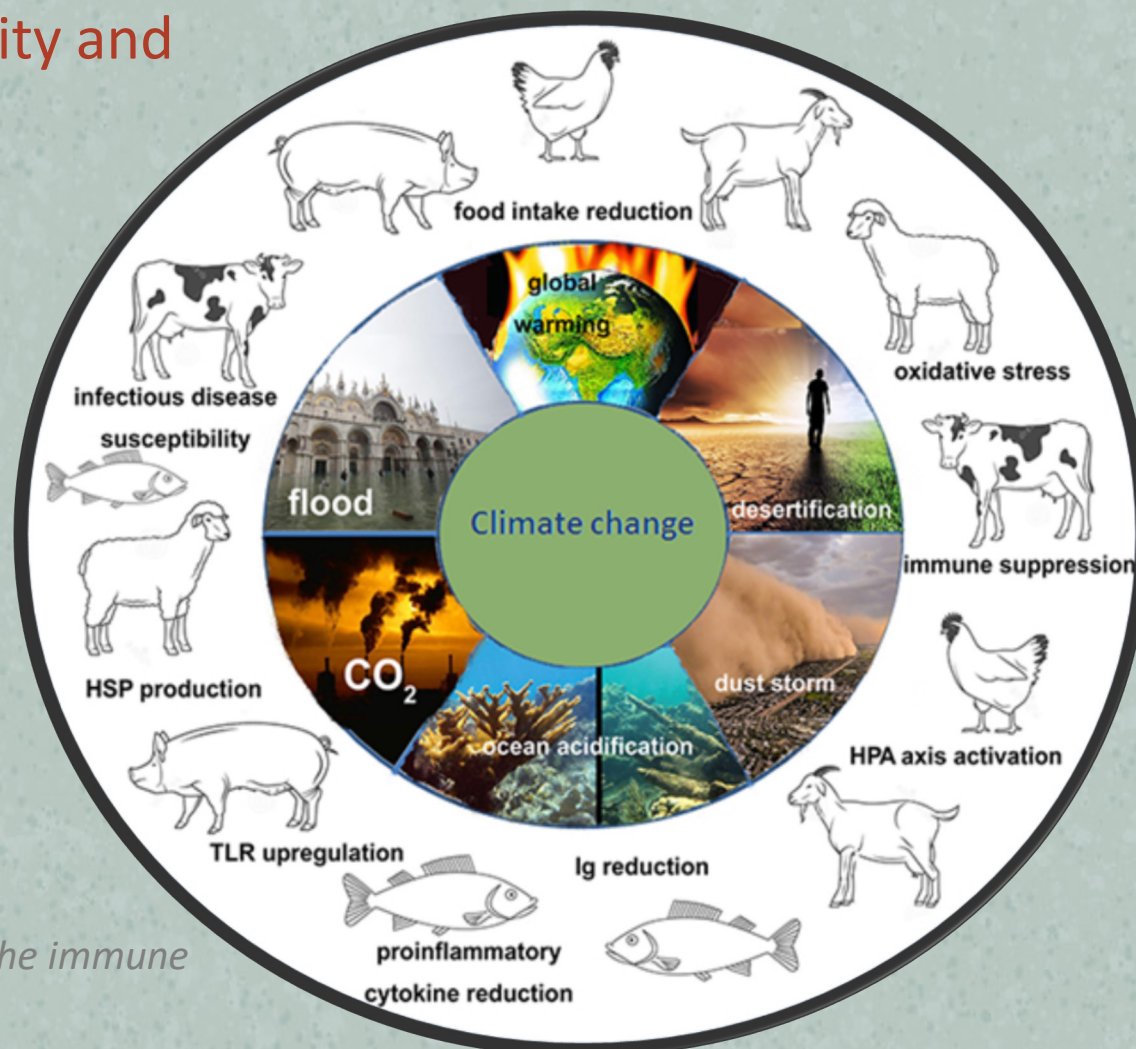


Figure 2 . The impact of climate change on the immune system of farm animals [2].





Immunological strategies



❑ **Tropical breeds** (camels, zebu and tarparkar cattle, autochthonous breeds - Osmanabadi goats and African Damara sheep), develop more adaptive immunity to heat stress conditions and regional pathogens

❑ **FAO catalog of "resistant" breeds:** 59 cattle breeds, 33 sheep breeds, 6 goat breeds, 5 horse breeds and 4 buffalo breeds, resistant to trypanosomiasis, endoparasites, dermatophilosis, tick infestation, etc.

❑ **Goats** are characterized by a higher number of lymphocytes than neutrophils, which indicates superior immunity.



<https://www.cfsph.iastate.edu/thelivestockproject/vectors-and-disease-spread-in-humans-and-animals/>

Anatomical-morphological strategies



- ❑ **Primary** anatomical changes: changes in the size of the body and body parts, color and type of hair and in the respiratory system
- ❑ **Specific** morphological characteristics such as larger salivary glands, a larger surface area of the absorptive mucosa, an increase in the volume of the front part of the digestive tract when consuming fiber-rich meals.

Hair color, type and density

- In tropical regions, **the light hair** of animals plays a significant role in reflecting solar radiation and minimizing heat absorption .
- The physical structure of the hair is crucial for thermoregulation - **smooth, short and thin hair, fewer** hair follicles per unit area allow maximum heat dissipation during stressful conditions.
- **In sheep** , thick woolly fur is insulation in cold conditions and helps regulate body temperature in thermal extremes.
- sheep's **carpet-wool type and thick tail** provide heat protection and prevent overheating in arid regions.



Anatomical-morphological strategies



Body size

- Changes in body size, such as a **reduction in** body size in warmer conditions may be adaptive responses to climate change.
- Smaller-sized animals have a **larger surface-to-volume ratio**, which enables **better heat dissipation** in warmer conditions.
- **Dwarf breeds** of cattle are better adapted to a warmer climate

Respiratory system

Adaptive changes: development of greater lung capacity or changes in breathing patterns (panting).

Body parts-extremities

- 'Allen's rule' refers to variations in animal morphology in different climates, with animals in **warmer regions** having **larger limbs** relative to overall body size.
- **Larger surfaces for sweating or panting**, along with increased blood flow to peripheral tissues, enable **effective regulation** of body temperature and reduce the risk of hyperthermia.



Funded by the
European Union



Funded by the
European Union



Anatomical-morphological strategies

Morphological adaptations in different types of farm animals

❑ **Goats** have the greatest adaptability:

- In dry conditions, they can radiate heat through their horns and survive on minimal vegetation (Boer and Nubian goats, for example).
- Boer and Nubian goats, with their long pendulous ears and wrinkled skin, survive better in the challenging arid conditions.

❑ **Sheep** are less tolerant, but their wool still provides some protection from high temperatures.

- Sheep **with hair instead of wool tolerate heat better**, and some breeds such as the thick-rumped Red Maasai and Sahelian sheep thrive in conditions with limited water availability and sparse vegetation.
- **The South African Dorper and the Karakul sheep** in the deserts of Central Asia do well in dry conditions, **storing fat in their tails**, which has a similar function to a camel's hump.



USV 1842



Funded by the European Union

Anatomical-morphological strategies

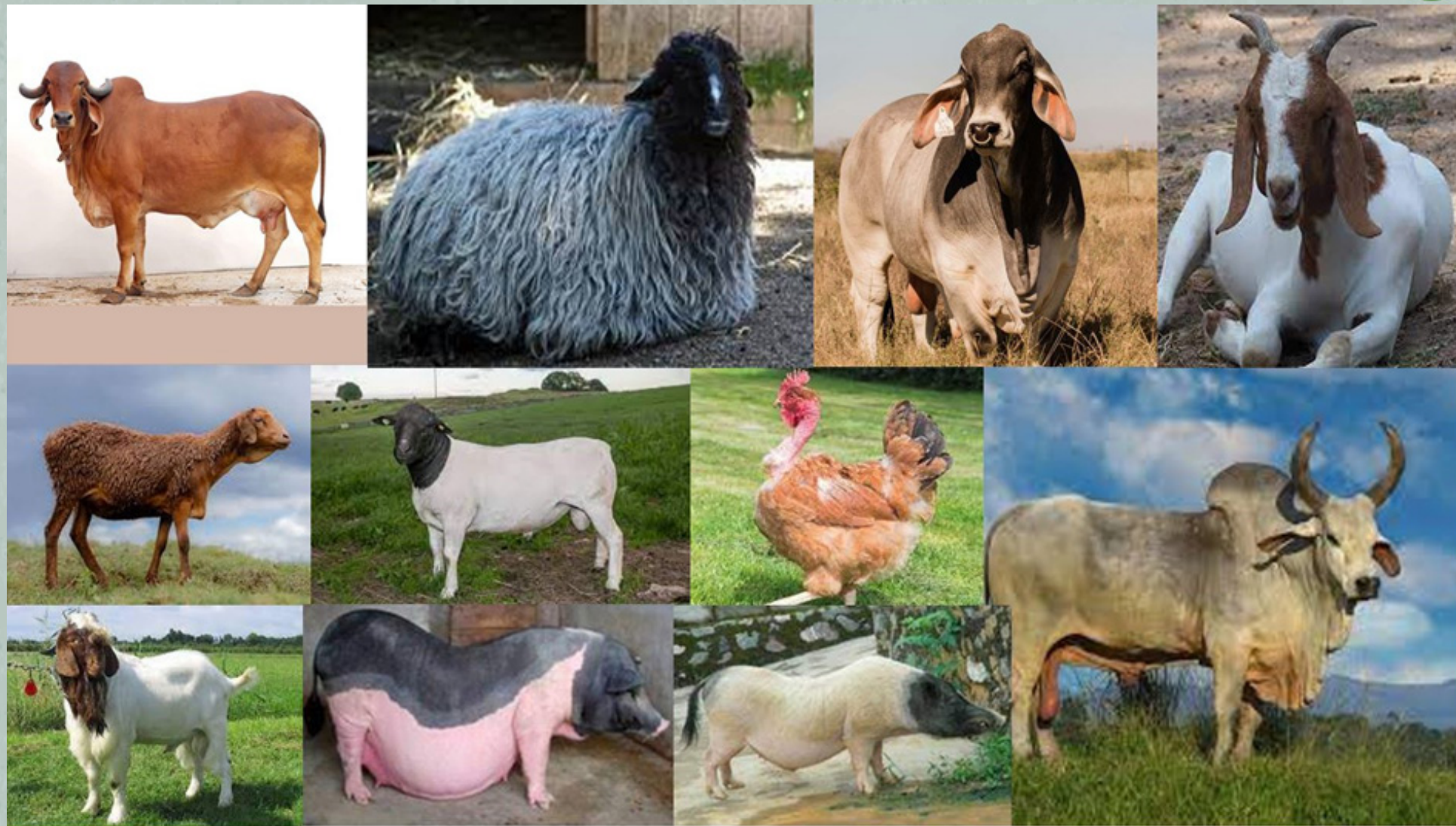


Figure 2: Morphological characteristics of climate-resistant species of domestic animals



Anatomical-morphological strategies



Morphological adaptations in different types of farm animals

- ❑ **Continental breeds of cattle**, especially highly productive dairy breeds, are susceptible to the influence of high temperatures, unlike their tropical relatives.
 - For a greater ability to survive in changing climatic conditions, it is recommended to introduce suitable genes from the genotype of tropical cattle (e.g. "slick" smooth coat gene)
- ❑ **In poultry**, the lack of feathers on the neck in the bare-necked species of hens, gives a marked advantage in dealing with heat stress.
 - Poultry with **larger crests and earrings also** tolerate high T.
- ❑ **Pigs** are the most sensitive to heat stress, due to their subcutaneous fat, lack of insulating fur, small lungs and inability to sweat.
 - **Durok** is moderately resistant to heat stress, while certain breeds from the warmer regions of South China possess heat resistance traits that may aid in genetic solutions for adaptation.



Funded by the
European Union

Behavioral strategies



- ❑ include **changes in daily activities and behavioral patterns** to alleviate the impact of heat stress and maintain thermal homeostasis:
 - **Seeking shady and cooler areas, bathing or spraying with water** are strategies by which domestic animals reduce exposure to direct sunlight and cool down.
 - **Poultry** cools down by spreading its wings, while **pigs** being the most sensitive, cool down in the mud and lie on cooler surfaces .
 - **Cattle** prefer the shade of trees vs. artificial protective structures because tree leaves provide highly efficient evaporative cooling.
 - With increasing thermal load, **cows shorten their resting time** and spend more time in a standing position. Thus, they increase the surface area of the body and facilitate the loss of heat through evaporation.



Funded by the
European Union



Behavioral strategies



Figure 3: Behavioral patterns leading to cooling in different species of domestic animals

Behavioral strategies



- Changes in behavioral eating patterns imply **reduced food intake** in order to reduce the metabolic load of the body.
- Cows switch to **night grazing** at extremely high daytime temperatures.
- With increasing thermal load, **the frequency of defecation and urination decreases**, primarily depending on the availability of food, water and ambient temperature.
- **The need for water increases:**
 - cows prefer water of moderate temperature.
 - giving cold water is recommended
- ❑ The ability of domestic animals to exhibit certain forms of behavior during heat stress reflects their **innate and instinctive** understanding of environmental cues and their ability to adjust their usual behavioral patterns to adapt.



USV 1842



Funded by the European Union

Sources



- [1] Sejian , V., Bhatta , R., Gaughan , JB, Dunshea , FR, & Lacetera , N. (2018). Review: Adaptation of animals to heat stress. *Animal*, 12(s2), s431–s444.
- [2] Filipe, JF, Valentina, H., Giulio , C., Daniele, V., & Federica, R. (2020). Floods, hurricanes, and other catastrophes: A challenge for the immune system of livestock and other animals. *Frontiers in Veterinary Science*, 7. <https://doi.org/10.3389/fvets.2020.00016>



Funded by the
European Union



Funded by the
European Union



Human Adaptation Strategies

Animal Genetics, Physical Modification,
Feed Management, Livestock Management
System

Dr. Dušica Ostojić Andrić

Introduction



- ❑ The IPCC defines adaptation as actions taken to **reduce the vulnerability** of natural and anthropogenic environments system to the effects of current or expected climate change.
- ❑ It is based on **the application and practices** that help animals adapt to climate change and improve their performance .
- ❑ **Anthropogenic adaptation strategies** include:
 - breeding domestic animals ,
 - modifications of the production and management system,
 - institutional and political changes



USV 1842



Funded by the
European Union

Introduction

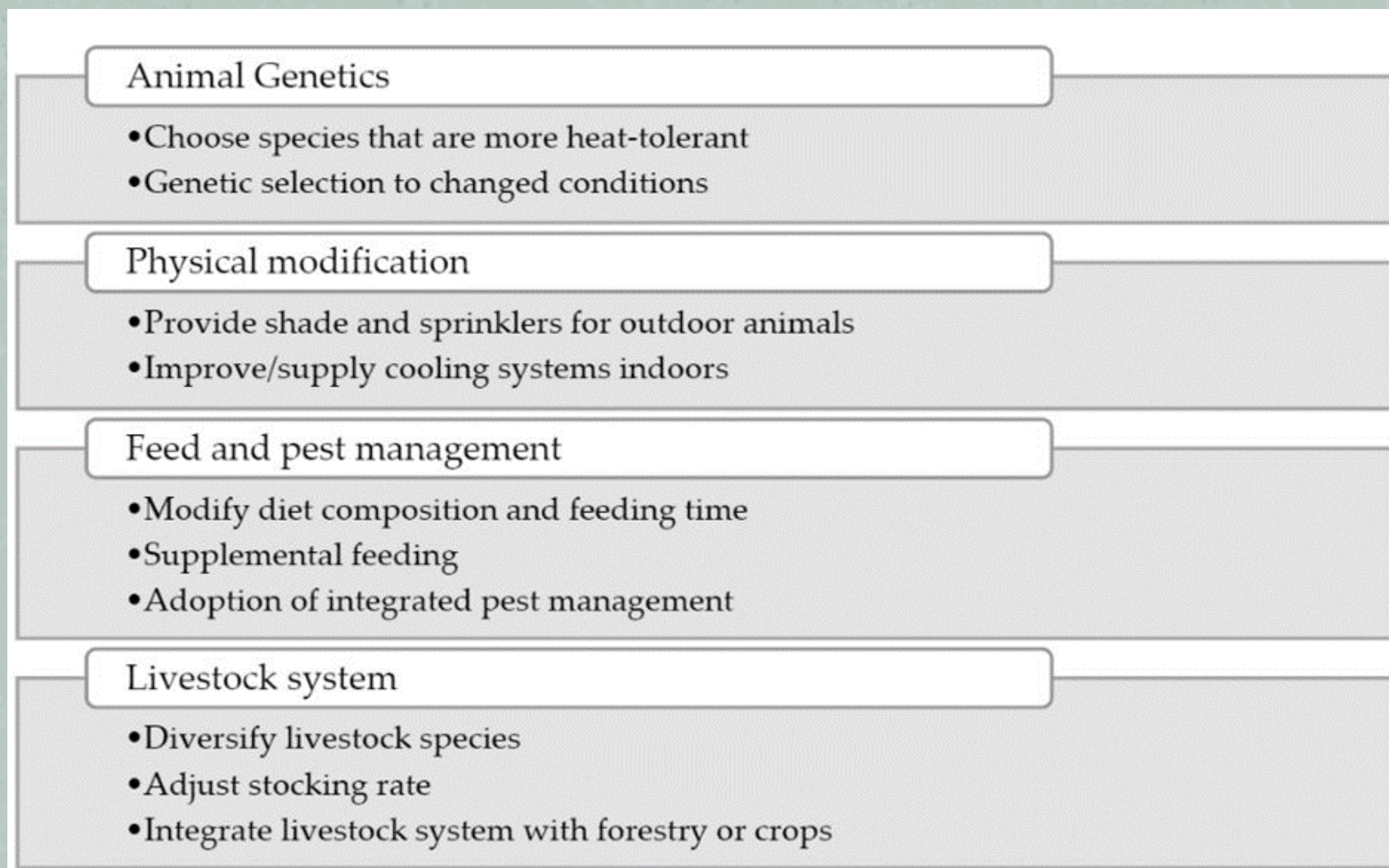


Figure 1. Summary of human adaptation strategies [1].





Animal Genetics

- ❑ **Selective breeding** of domestic animals favored genotypes with **high energy requirements** and increased production of **metabolic heat**.
- ❑ Some breeds of domestic animals show greater resistance to heat stress, which is the result of their adaptive abilities and evolutionary advantages.
- ❑ **Adaptations**- thin, short and smooth hair, larger limbs and increased skin and lung surface area play a key role in domestic animals' ability to adapt to new climatic conditions.
- ❑ **Manipulation of the genetic material** of domestic animals is therefore one of the measures of adaptation.



<https://www.pexels.com>



Funded by the
European Union

Animal Genetics



❑ Conventional, marker-assisted and genomic selection

- The phenotypic expression of traits is highly dependent on the genotype, which allows for different forms **genetic manipulation** for the purpose of adaptation.
- Physiological indicators of heat stress are traits with low heritability, which limits the potential for genetic improvement through **conventional selection**.



<https://organicconsumers.org/>





Animal Genetics

- ❑ Marker-assisted selection and genome-wide association studies open possibilities for faster selection of thermo-resilient animals.
- ❑ It is necessary to precisely determine the genomic variation associated with thermo-resilience for progress in genomic selection .
- ❑ Advances in specifying candidate genes associated with heat tolerance and production traits enable the application of marker-assisted selection and gene editing initiatives in livestock breeding.
- ❑ Crossbreeding and gene editing are additional options for manipulating animal genetics and combating the effects of climate change on livestock.

Animal Genetics

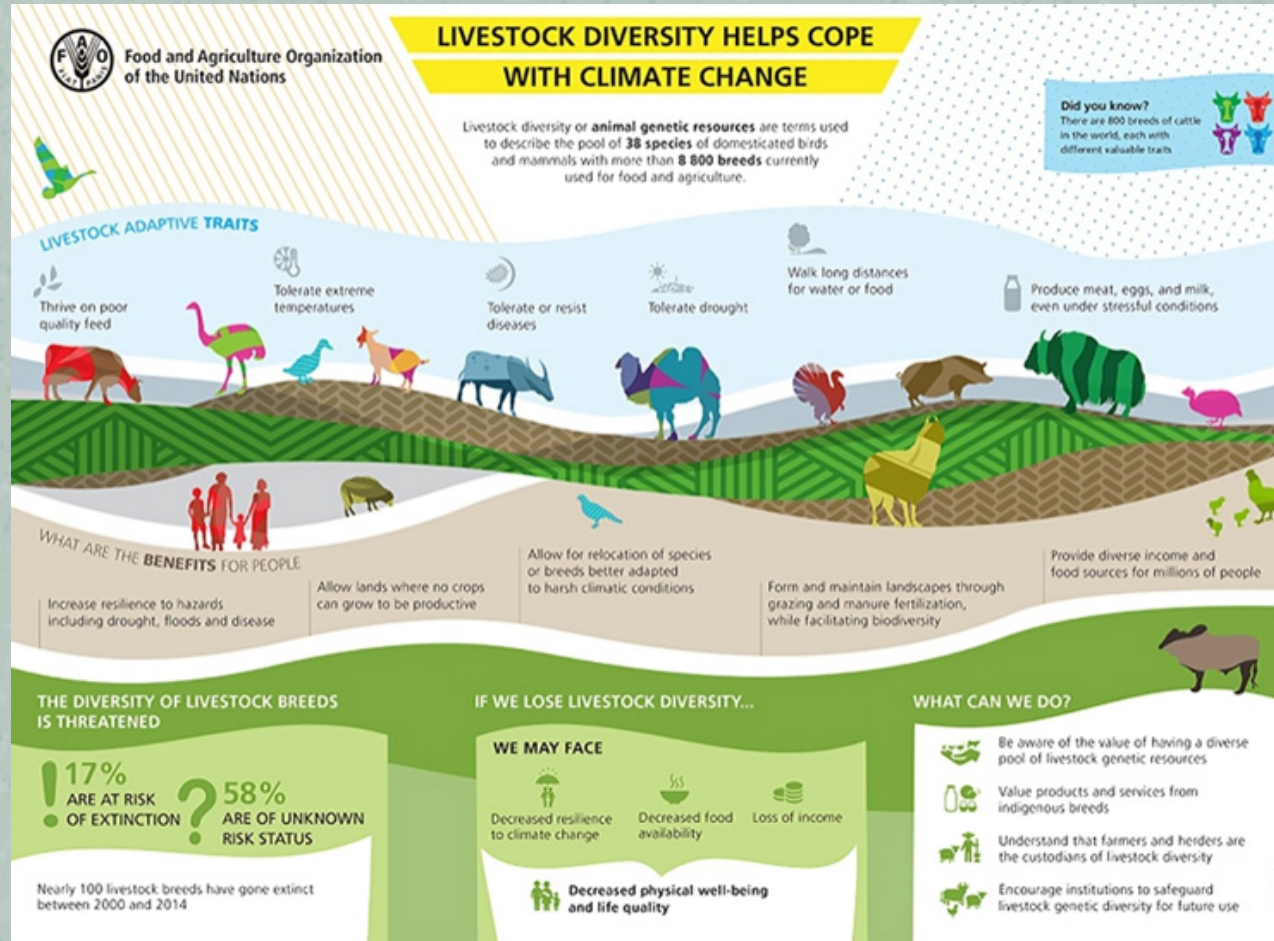


- ❑ Adaptation of tropical breeds to climatic vulnerability zones can be a sustainable strategy for coping with climate change.
 - The risk represents the ability of animals to survive in new conditions, their resistance to diseases as well as often lower productivity
- ❑ Crossing of tropical and locally adapted breeds with high-yielding breeds
 - Crossbreds between taurine and zebu cattle have better resistance to heat, disease and lack of water with higher productivity.



Funded by the
European Union

Animal Genetics



□ Locally adapted breeds (AnGR) can be used for the development of genotypes adapted to climatic changes.

□ Many AnGR come from dry land region (camel, yak, etc.)

Figure 2. Presentation of the role and benefits of genetic resources in the strategy and adaptation to climate change [2].

□ AnGR have evolved in conditions of adaptation to extreme climatic conditions and are able to face seasonal nutritional deficiencies, parasitic and other diseases .

Animal Genetics



- ❑ The application of biotechnology for the introduction of thermo-resilient genes- gene editing is a promising approach in climate change adaptation strategies.
- ❑ Several genes have been identified that play a key role in regulating various physiological processes that contribute to thermo-resilience and protection of cells from oxidative stress .
- ❑ Heat shock proteins produced by thermal stress protect the cell from oxidative damage and maintain its integrity
- ❑ By editing genes such as CRISPR-Cas9, thermo-resilience genes can be introduced into the genome of domestic animals, thereby increasing their ability to adapt to heat stress.



USV 1842



Funded by the
European Union

Physical Modifications



❑ **Environmental changes** provide a sustainable approach to alleviating heat stress in livestock.

1) **Modifications in the free housing systems (pasture, graze):**

provide protection from solar radiation: natural shade, shading, solar shading as sustainable energy-saving solutions, sprinklers, combined systems).



Figure 3. An example of an innovative solar radiation protection system [3].



Figure 4. An example of a sprinkler system for cooling grazing cows [4].

Physical Modifications

- 2) Modifications in the indoor housing system include natural ventilation systems, use of insulation and optimization of barn orientation, while artificial ventilation and substrate cooling systems can be applied as additional measures .

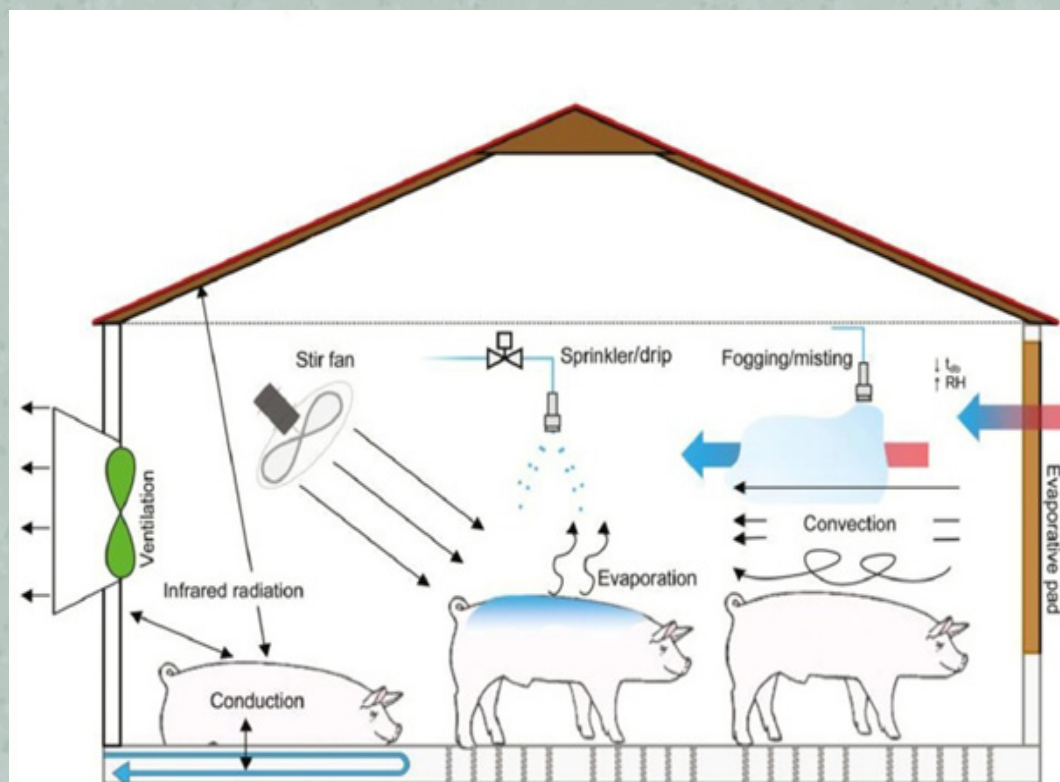


Figure 5. Example of a ventilation and cooling system for large pig farms [5]

- Precision agriculture provides optimal solutions for regulating the stable microclimate
- Caution due to significant investment and operating costs in the operation of cooling systems
- Efforts to apply green technologies.

Feed Management



- ❑ Application of nutritional strategies should **reduce the physiological effort** associated with heat stress and **boost animal performance** by:

- maintaining **hydration**,
- **electrolyte** balance and
- **antioxidant** status.

- ❑ Strategies include:

- adjusting **the composition of the diet**,
- changes in **the time and frequency of feeding**,
- adoption of efficient **water management** practices .



Funded by the
European Union

Feed Management



- ❑ Ensuring adequate access to clean drinking water and optimizing water use efficiency in feed production can mitigate the impact of water scarcity and drought on livestock.
 - Providing livestock with clean and abundant water near the feeding area contributes to improved performance by reducing body temperature.
 - Combining ad libitum feeding with wetting meals improves food intake compared to feeding dry meals .
- ❑ Adding electrolytes alleviates heat stress by replacing water losses through sweating and panting.
- ❑ Supplementation with antioxidants (vitamins E and C) in the fight against oxidative stress caused by hyperthermia.



Funded by the
European Union

Feed Management



❑ Including fat in the diet alleviates heat stress:

- Fats are a key source of energy in conditions of heat stress (meeting needs with smaller amounts of food).
- Fat metabolism releases less heat than carbohydrates or proteins,
- The taste of feed improves, performance improves

❑ Supplementation with antioxidants (vitamins E and C) in the fight against oxidative stress caused by hyperthermia .

❑ Addition of amino acids, e.g. lysine and methionine in pigs promotes protein synthesis and muscle mass

❑ Additives aid heat dissipation, water retention and regulate hormonal responses to heat stress

❑ Probiotics, prebiotics and phyto-supplements improve gut health and nutrient absorption, which increases resistance to heat stress.





Feed Management

- ❑ **Adjusting meal times:** early in the morning or late in the evening when temperatures are lower.
- ❑ **Adjusting the frequency of meals:** smaller and more frequent meals promote digestion and absorption of nutrients, reducing the metabolic heat generated during digestion.
- ❑ **The use of alternative sources of food** (agricultural by-products, insect-based feed) mitigates the impact of food fluctuations due to climate change and provides valuable nutrients.
- ❑ **Optimizing nutrition efficiency** (selective breeding and precise feeding techniques) minimizes the use of resources and production costs , while increasing productivity.
- ❑ **The integration of thermo-resilient forage crops** sustains livestock production in arid regions and increases resilience to climate variability.



TAGEM
R&D AND INNOVATION



Faculty of Agriculture
and Technology
University of South Bohemia
in České Budějovice



Funded by the
European Union



Livestock Management System

Management of livestock production systems involves a range of strategies, including:

- 1) **Livestock diversification** allows farmers to improve resilience, resource use and adaptability to changing climate conditions:
 - Traditional breeders already use this strategy, and small farms in developing countries show greater resilience to climate change due to species diversity and flexibility in changing them.
 - Projections indicate that with the increase in T, livestock farmers switch from raising cattle and poultry to raising small ruminants
 - **Animal genetic resources** can play an important role in this climate change adaptation strategy.



USV 1842



Funded by the
European Union

Livestock Management System



- 2) Adjustment of herd size and population density in order to reduce the risk of overgrazing and depletion of forage resources during warm periods.
- 3) The integration of animal husbandry with forestry and/or arable crops has synergistic advantages:
 - improves soil fertility and circulation of nutrients
 - economically justified-provides additional sources of income i improves farm resistance to market fluctuations .
 - ecologically justified-increased carbon sequestration and quality of Land.



<https://www.pexels.com/>

Sources



[1] Cheng , M., McCarl , B., & Fei , C. (2022). Climate Change and Livestock Production: A Literature Review. *Atmosphere*, 13(1), Article 1.

[2]FAO:Livestock diversity helps cope with climate change. Retrieved from <https://www.fao.org/3/i6232e/i6232e.pdfhttps://www.fao.org/3/i6232e/i6232e.pdf>

[3] Sharpe, KT, Heins , BJ, Buchanan, ES, & Reese, MH (2021). Evaluation of solar photovoltaic systems to shade cows in a pasture-based dairy herd. *Journal of Dairy Science*, 104(3), 2794-2806. <https://doi.org/10.3168/jds.2020-18821>.

[4] Stone, A. (2020). Relieving heat stress in dairy cattle. *Research OUTREACH*, 119. Available at: <https://researchoutreach.org/articles/relieving-heat-stress-in-dairy-cattle/>

[5] Hu, Z., Yang, Q., Tao, Y., Shi, L., Tu , J., & Wang, Y. (2023). A review of ventilation and cooling systems for large-scale pig farms. *Sustainable Cities and Societies*, 89, 104372.



USV 1842



Funded by the
European Union



Funded by the
European Union



POSSIBILITIES FOR ENCOURAGING AND IMPLEMENTING MITIGATION AND ADAPTATION STRATEGIES

Dr. Dušica Ostojić Andrić

Introduction



- ❑ **Livestock production** is key to global food security and economic development.
- ❑ Climate change is **a direct threat**, requiring quick and effective action.
- ❑ **Encouraging and implementing strategies** for adapting and mitigating the impact of climate change in livestock production is necessary.
- ❑ **The support of social and governmental institutions** is important for the successful implementation of strategies for adaptation and mitigation of the impact of climate change on animal husbandry .
- ❑ **Focus** is on the role of state institutions, training and technological advancement.



Funded by the
European Union

Policy and Institutional Support



- ☐ **Laws and regulations** are key in forming a legal framework to support adaptation to climate change in animal husbandry.
- ☐ **Understanding the variability** of climate change impacts on different livestock systems is essential for creating effective policies and practices
- ☐ **Governments can direct animal husbandry** towards reducing emissions and impact on the environment through regulatory standards for breeding practices in animal husbandry.
- ☐ **Regulations** can include emission limits, waste management and nutrient management plans, as well as the implementation of sustainable practices.
- ☐ Some of the common regulations include emission limits, waste management and the implementation of sustainable practices.



Funded by the
European Union

Policy and Institutional Support



- ❑ The most frequently used regulations and measures are the following:
 - **Carbon tax:** Farmers are encouraged to invest in technologies and practices that reduce emissions and increase efficiency .
 - **Land use planning:** the expansion of livestock production into ecologically sensitive areas is prevented (forests, wetlands) and promote sustainable land management practices.
 - **Water management:** helps to solve water scarcity and quality issues related to livestock production (consumption limits, conservation measures and pollution protection guidelines)
 - **Farm animal welfare:** promoting the welfare of farm animals reduces stress and the occurrence of disease, which leads to more efficient use of resources and lower gas emissions per unit of production.



Funded by the
European Union

Policy and Institutional Support



- **Various financial mechanisms** such as carbon taxes, payments for ecosystem services (PES) or subsidies to combat climate change provide financial incentives for livestock producers to **adopt climate friendly practices**. These incentives help offset the costs of implementing new technologies or switching to more sustainable farming methods.
- **Support for renewable energy**: promoting the adoption of renewable energy technologies through incentives (solar panels or biogas digesters on farms) aims to encourage farmers to produce clean energy on farm, reducing reliance on fossil fuels.
- **Funding for research and innovation**: The EU provides funds for projects aimed at improving sustainability in agriculture, including livestock production.



Funded by the
European Union

Building Awareness and Understanding



- ❑ Despite experiencing firsthand the detrimental impacts on their production, **farmers frequently harbor doubts** regarding the veracity of claims surrounding the existence of climate change,
- ❑ Hence, there is a need to **cultivate trust in scientific knowledge**, as well as in government actions guided by these facts.
- ❑ **The trainings** strengthen farmers' awareness and understanding of the impacts of climate change on livestock production.
 - By acquiring knowledge about potential risks and vulnerabilities, as well as adaptation and mitigation measures, farmers can make informed decisions to protect their production.
- Beyond farmers, **informing consumers** about the environmental impact of their food choices can boost demand for sustainably produced livestock products.



Funded by the
European Union

Building Awareness and Understanding

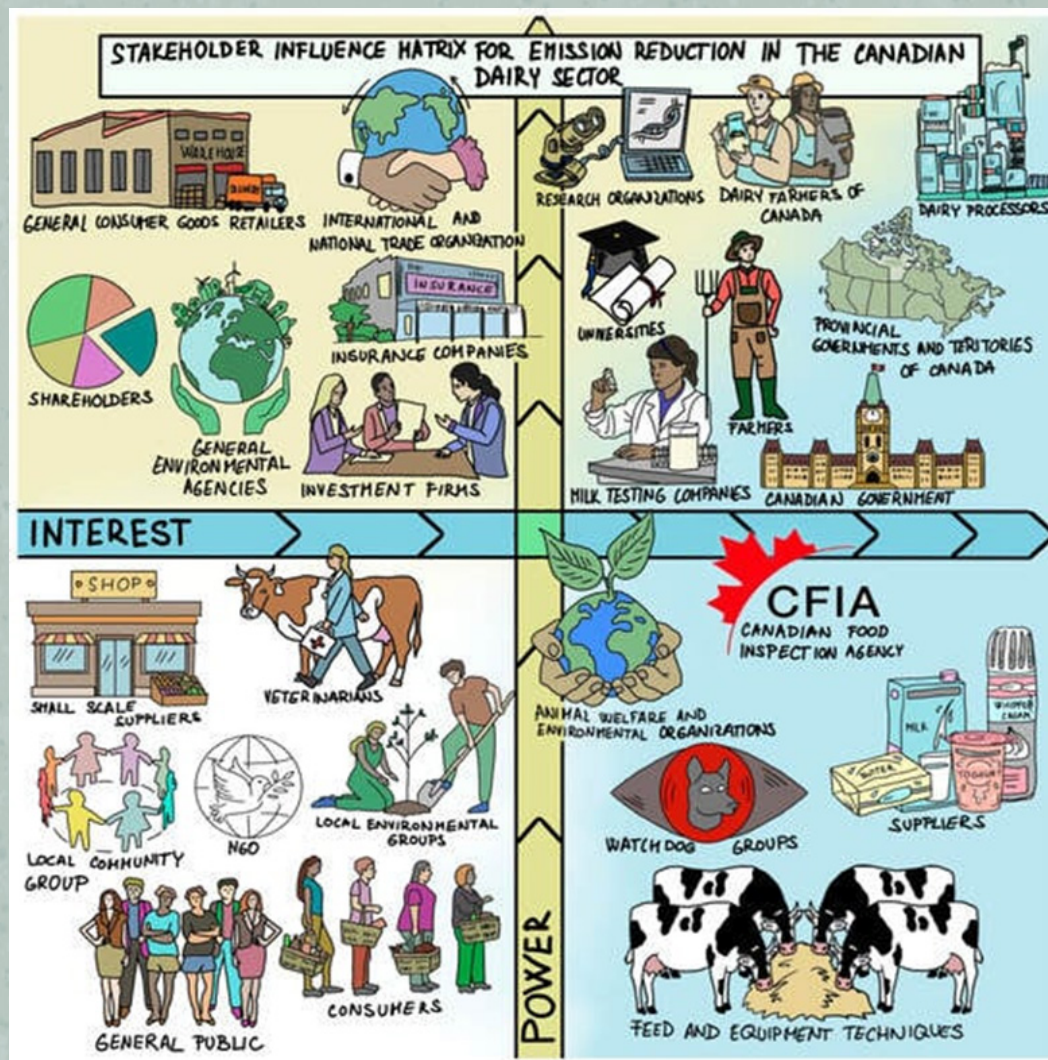


Figure 1. An example of how different groups or individuals can impact efforts to reduce greenhouse gas emissions within the dairy industry in Canada [1].

Training and capacity building initiatives



- ❑ Farmers may lack the knowledge or technical skills needed to adopt sustainable farming techniques.
- ❑ The campaigns aim to educate farmers about the impacts climatic change and available strategies For mitigation and adaptation this changes .

Figure 2. Training activities within the CLIAVE Erasmus+ project aim to improve farmers' knowledge of climate-smart livestock practices.

- ❑ Consultations, workshops and demonstration farms provide practical guidance and experience in areas such as soil and water conservation, animal husbandry, feed efficiency and resource conservation.





Funded by the
European Union

Access to Resources



- ❑ **Training and government interventions** can improve farmers' access to the resources and technologies needed to adapt to and mitigate climate change:
 - access to climate -resilient crop varieties and animal breeds
 - access to renewable energy solutions.



<https://pixabay.com/>

Research, Innovation, Collaboration and Knowledge Sharing



- ❑ Investing in research and development of new technologies and innovations adapted to the livestock sector can help improve resilience to climate change :
 - breeding of livestock breeds more resistant to heat,
 - development of food additives that reduce methane emissions
 - designing energy-efficient housing systems etc.
- ❑ Advances in precision agriculture, remote sensing and digital monitoring tools allow farmers to optimize resource use, minimize environmental impacts and respond effectively to climate variability.



Funded by the
European Union



USV 1842



Funded by the
European Union

Research, Innovation, Collaboration and Knowledge Sharing



Figure 3. Contemporary model for sustainable dairy farming [1].

Research, Innovation, Collaboration and Knowledge Sharing



- ❑ Encouraging cooperation and exchange knowledge among those interested parties, including farmers, researchers, creators policies and representatives industry, can make it easier exchange ideas, experiences and the best practices .
- ❑ Farmer networks, research consortia, and multi-stakeholder partnerships can foster collaboration and collective action encourage cooperation and collectively action .
- ❑ Strengthening capacity for innovation and providing support to farmers are vital to the expansion of sustainable and regenerative agriculture, thereby maximizing its positive effects.



Funded by the
European Union

Risk Management



- ❑ Livestock producers face a **range of climate-related risks**, including heat stress, drought, disease outbreaks and food shortages.
- ❑ Strategies adjustments and mitigations can help in **mitigation these risk** and construction resilience in coping with uncertainty .
- ❑ Through training in risk assessment and management techniques, as well as access to insurance and financial support mechanisms, farmers can better cope with climate-related challenges.



<https://pixabay.com/>



Funded by the
European Union

Conclusion

- ❑ Mitigation and adaptation strategies are essential for building climate resilience in livestock production systems.
- ❑ Training programs, policy interventions, and technological innovations offer promising avenues for fostering and implementing these strategies.
- ❑ By investing in education, policy support and research and development, stakeholders can promote sustainable practices that increase the productivity, profitability and environmental sustainability of livestock farming.



Funded by the
European Union

Sources



[1] Neethirajan, S. Innovative Strategies for Sustainable Dairy Farming in Canada amid Climate Change.(2024). Sustainability, 16, 265. <https://doi.org/10.3390/su16010265>



USV 1842



Funded by the
European Union