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RESILIENCE OF PEOPLE AND ECOSYSTEMS UNDER CLIMATE STRESS

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**The recommendations and other materials included in this booklet are based on papers and data presented at the Pontifical Academy of Sciences (PAS) workshop on July 13 and 14, 2022 at the Vatican. Additional data were collected from documents published after the workshop. References for the quantitative numbers in the declaration are given in the last chapter of the booklet, titled "Supporting Data". PAS will also publish the full-length proceedings of the workshop that includes all the papers presented at the workshop.*

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To the Participants in
the Conference on Resilience of People
and Ecosystems under Climate Stress

I offer cordial greetings to the organizers and participants in the Conference on *Resilience of People and Ecosystems under Climate Stress* sponsored by the Pontifical Academy of Sciences. I thank His Eminence Cardinal Peter Turkson, Chancellor of the Academy, His Excellency Bishop Marcelo Sánchez Sorondo and all those responsible for making this gathering possible.

The phenomenon of climate change has become an emergency that no longer remains at the margins of society. Instead, it has assumed a central place, reshaping not only industrial and agricultural systems but also adversely affecting the global human family, especially the poor and those living on the economic peripheries of our world. Nowadays we are facing two challenges: lessening climate risks by reducing emissions and assisting and enabling people to adapt to progressively worsening changes to the climate. These challenges call us to think of a multi-dimensional approach to protecting both individuals and our planet.

The Christian faith offers a particular contribution in this regard. The Book of Genesis tells us that the Lord saw that all he had made was very good (cf. *Gen* 1:31) and entrusted human beings with the responsibility of being stewards of his gift of creation (cf. *Gen* 2:15). In the Gospel of Matthew, Jesus reinforces the goodness of the natural world by reminding us of God's care for all his creatures (cf. *Mt* 6:26.28-29). In light of these biblical teachings, then, care for our common home, even apart from considerations of the effects of climate change, is not simply a utilitarian endeavour but a moral obligation

for all men and women as children of God. With this in mind, each of us must ask: "What kind of world do we want for ourselves and for those who will come after us"?

To help answer that question, I have spoken of an "ecological conversion" (cf. *Laudato Si'*, 216-221) which demands a change of mentality and a commitment to work for the resilience of people and the ecosystems in which they live. This conversion has three important spiritual elements that I would offer for your consideration. The first entails gratitude for God's loving and generous gift of creation. The second calls for acknowledging that we are joined in a universal communion with one another and with the rest of the world's creatures. The third involves addressing environmental problems not as isolated individuals but in solidarity as a community.

On the basis of these elements, courageous, cooperative and far-sighted efforts among religious, political, social and cultural leaders on local, national and international levels are needed in order to find concrete solutions to the severe and increasing problems we are facing. I am thinking, for example, of the role that the most economically advantaged nations can play in reducing their own emissions and providing financial as well as technological assistance so that less prosperous areas of the world may follow their example. Also crucial is access to clean energy and drinkable water, support given to farmers around the world to shift to climate resilient agriculture, a commitment to sustainable paths of development and to sober lifestyles aimed at preserving the world's natural resources and the provision of education and healthcare to the poorest and most vulnerable of the global population.

Here I would also mention two additional concerns: the loss of biodiversity (cf. *Laudato Si'* 32-33) and the many wars being waged in various regions of the world that together bring with them harmful consequences for human survival and wellbeing, including problems of food security and increasing pollution. These crises, along with that of the earth's climate, show

that "everything is connected" (*Fratelli Tutti*, 34) and that promoting the long-term common good of our planet is essential to genuine ecological conversion.

For the above-mentioned reasons, I have recently approved for the Holy See, in the name and on behalf of Vatican City State, to accede to the United Nations Framework Convention on Climate Change and the Paris Agreement, with the hope that "although the post-industrial period may well be remembered as one of the most irresponsible in history, nonetheless there is reason to hope that humanity at the dawn of the twenty-first century will be remembered for having generously shouldered its grave responsibilities" (*Laudato Si'*, 165).

Dear brothers and sisters, I am pleased that your work in these days is dedicated to examining the impact of changes in our climate and seeking practical solutions that can be implemented promptly in order to increase the resilience of people and ecosystems. In working together, men and women of good will can address the scale and complexity of the issues that lie before us, protect the human family and God's gift of creation from climate extremes and foster the goods of justice and peace.

With the assurance of my prayers that your Conference will bear good fruit, I invoke upon all of you the abundant blessings of Almighty God.

From the Vatican, 13 July 2022

Francis

I. Declaration and Recommended Actions

***The Climate Challenge**:* **A Grave Danger**. The continued emissions of heat trapping gases at record levels have transformed climate change into climate disruption. Poor and vulnerable populations (about 4 billion) are at the receiving end of the devastation despite their low emissions (only 15%). World food and water security is seriously threatened, partly due to climate disruption. The northern hemisphere has witnessed a six-fold increase in large heatwaves since the 1980s, and such weather extremes have adversely impacted 4 billion people since the 1990s, posing grave threats to ecosystem health and public health, including mental health. In about ten years, the heating of the planet's surface is projected to amplify by about 50% to 1.5°C, followed by more heating beyond. The proportional intensification of climate extremes along with the crossing of natural and social tipping points will strike rich and poor. Mass displacements and migrations of people could pose political instabilities. Since such changes are irreversible for centuries, generations unborn will suffer. A full-blown climate crisis is likely by early 2030s.

Climate Resilience: **A New Approach.** The Pontifical Academy of Sciences, prompted by grave concerns about the climate crisis in the Anthropocene, convened a meeting during July 13-14, 2022 to recommend steps to forestall the crisis. The attendees viewed human-nature interactions through a triplet of interlinked crises: Climate, Biodiversity, and Inequality. The consensus was: *it is too late to rely just on mitigation. Adaptation to climate risks is overdue and must become a central theme of climate actions. A global effort to build climate resilience is needed, and the following recommendations placed on the agenda of COP27 and beyond.*

Recommendations: *Resilience building must rest on three pillars:* ***Mitigation, Adaptation*** *&* ***Transformation.***

Mitigation: *Reduce climate risks*

1) *Bending the warming curve down*: Bend and flatten the warming curve below 2°C before 2050 and bend it further below to 1.5°C before 2100, through deep cuts in emissions of CO_2 and other heat-trapping pollutants; and extraction of at least a third of the 1.2 trillion tons of CO_2 from the atmosphere. The wealthy billion must drastically reduce their emissions and provide financial/technological assistance to the vulnerable 4 billion people to enhance their adaptive capacity and to build their resilience.
2) *Nature-based solutions***:** Include nature-based climate solutions for emission reductions, that bring in oceans, mangroves, agroforestry, working farmlands and forests. These solutions also provide adaptation benefits and offer powerful options for addressing biodiversity and inequality with huge co-benefits for health of people and ecosystem.

Adaptation: *Reduce exposure and vulnerability to unavoidable climate risks.*
Exposure & vulnerability reduction has three faces: Reductions in sensitivity to climate change; Reductions in risk exposure; & enhancement of adaptative capacity. There are limits to adaptation and hence adaptation has to be integrated with mitigation actions to avoid crossing the limits. Furthermore, isolated adaptation actions might inadvertently result in maladaptation, which can be avoided by an integrated resilience approach and choosing those actions with co-benefits to biodiversity.

3) *Inequality*: Initiate a major effort to help the poor and vulnerable four billion to adapt to climate risks now. Affordable access to clean energy, water, health care, sustainable farming and resilient infrastructures must be part of the milestones. It is, moreover, critical to develop novel legal instruments for the protection of people displaced by anthropogenic global warming. One important step forward would be the introduction of a "Climate

Passport" to enable self-determined and dignified survival migration of individuals in response to severe climate impacts. This instrument could be modeled after the legendary "Nansen Passport", which was eventually accepted by more than fifty states. It guaranteed legal residence for displaced persons in the aftermath of World War I and allowed them to work in their host countries.

4) *Governance*: Solutions should be locally and nationally determined actions. Coordinate the available resources at various levels of government with the local actions.
5) *Food & water security*: Worldwide scaling up of the following are required: sustainable land and soil management, forest protection and agroforestry, advanced plant breeding, social protection with nutrition components, water use efficiency in farming, and access to clean drinking water and sanitation. Water security, already threatened perceptibly by global warming and related weather extremes, needs to become a visible element of climate change negotiations. A concerted effort is required to reduce food waste and excessive meat consumption.
6) *Construction and housing:* Transform settlements into carbon banks by prioritizing organic building materials in support of sustainable bio-economy and circularity through multiple material reuse, including such homes which transform todays' slum areas.
7) *Regional hotspots*: Special attention must be given to regional hotpots for climate stress: Amazon, Small Island nations, Drylands of Africa, Southern Africa, Mediterranean, Middle East, South Asia, NE China and South-West USA.

Transformation: *Change of lifestyle, transformation of society and ecosystems, to mitigate, adapt and bounce back.* This transformation is akin to an ecological conversion (Pope Francis' statement) and must integrate actions on the triplet of crises: climate, biodiversity, and inequality.

8) Transformation of economic systems and societies by moving swiftly to renewable energy systems, applying incentives such as carbon pricing and regulations for reducing demand for emission-intensive goods, including policies that account for the values of nature and take us on a path of stewardship and restoration of Nature. We must also recognize the obligations of wealthy societies providing technological and financial assistance to the less wealthy, and of all societies to pursue scientifically and environmentally informed economic development.
9) Behavioral change of people, communities, and business is needed to achieve the transformation. A major new global initiative is required for mass education of everyone, from children to senior citizens, in ecological citizenship (*Laudato Si'*, para 211) and on sustainable living. Public, civil society and faith-based communities of all world religions can productively engage in this moral task.
10) The above recommendations require a major engagement of science. Science must assist in prioritization of evidence-based actions without losing focus on equity issues. The analyses of solutions must include the modeling of two-way natural/social systems interactions to achieve a transformational improvement in the predictive power of climate trajectories.

Faith and science can form trans-disciplinary alliances to deliver the requisite mobilization of public support for climate actions. Such alliances are feasible because protection of all of creation is the stated goal of all faiths. The Pontifical Academy of Sciences has been nurturing such alliances through series of meetings on climate change and sustainability for over two decades.

It is within our reach to become better stewards of the planet and make people and ecosystem bounce back from the multiple environmental crises to a safer, healthier, and sustainable world.

II. Extended Declaration with Problem Statement

Adapted from Ramanathan 2022; Proceedings of this workshop

Statement of the Problems

1. Climate change has become a central problem of world society. It is disrupting industrial and agricultural systems, adversely impacting the health of billions and water security, and most importantly imposing unprecedented harms on the poor and on those who are climate vulnerable, numbering over 3.3 billion people. It is also contributing significantly to loss of biodiversity and to the worsening of inequality within – as well as across – nations. These climate change-related consequences contribute directly and significantly to reduction of resilience.[1] This has become the age of humans: we have ushered in the Anthropocene.
2. We are now facing three interrelated challenges. The first is to bend the emissions curve as soon as possible to reduce climate risks. The second challenge is to reduce the pressure on nature and loss of biodiversity, as much as possible. And the third challenge is to enable and help people, especially the vulnerable 4 billion people, adapt to unavoidable climate changes.
3. The Pontifical Academy of Sciences has raised its deep concern about Climate Change and lack of action to address its root causes during the past three decades.[2] We refer to Pope Francis' seminal Encyclical *Laudato Si*', that highlighted key issues of climate change, inequality and destruction of nature. With this conference and statement, we draw attention to the accelerated risks resulting from climate change for people and planet, and particularly we focus on the urgent need to strengthen resilience with accelerated multilateral collaboration, improved policies, investments, social action, and behavioral change.
4. The planet crossed a major warming threshold (1°C) during the 2010 to 2020 decade, a warming not seen in the last 2000 years. It has reached about 1.2°C and is very likely to cross the 1.5°C warming threshold by early 2030s... that is, about 10 years from now. The 1.5°C warming is the threshold for dangerous warming. Everyone on the planet will be adversely affected, either directly or indirectly. The climate crisis is upon us, and it could get lot worse in about 10 years from now. With unchecked emissions, it is likely to cross the 2°C threshold before 2050 and the catastrophic warming threshold of 3°C to 4°C by end of this century.
5. Because the warming is associated with intensification of weather extremes such as heatwaves, extreme rainfall and floods, tropical storms such as hurricanes and cyclones, mega droughts and fires, climate change is adversely affecting the health of people, ecosystems, and biodiversity. The number of weather/climate/water-related disasters

[1] Resilience is understood as *the capacity of social, economic and ecosystems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure as well as biodiversity in case of ecosystems while also maintaining the capacity for adaptation, learning and transformation* (IPCC-WGII Report, 2022).

[2] Examples include:

- Reconstructing the Future for People and Planet https://www.pas.va/en/events/2022/reconstructing_the_future.html
- Dreaming of a Better Restart https://www.pas.va/en/events/2021/dreaming_restart.html
- Faith and Science: Towards COP26 https://www.wiltonpark.org.uk/faith-and-science-towards-cop26/ https://www.pas.va/en/news/2021/2021_cop26.html
- Health of People, Health of Planet and Our Responsibility Climate Change, Air Pollution and Health *Scripta Varia 139*. https://www.pas.va/content/dam/casinapioiv/pas/pdf-volumi/scripta-varia/sv_HealthOfPeopleHealthOfPlanet.pdf
- *Laudato si'* and the Path to COP22 *Scripta Varia 128* https://www.pas.va/en/publications/scripta-varia/sv128pas.html
- Fate of Mountain Glaciers in the Anthropocene *Scripta Varia 118* https://www.pas.va/en/publications/scripta-varia/sv118pas.html
- Geosphere-Biosphere Interactions and Climate https://www.pas.va/content/dam/casinapioiv/pas/pdf-volumi/scripta-varia/sv96pas.pdf

increased five-fold during the last 50-year period. Climate change is a global health crisis as well as an environmental crisis. A further increase in the warming beyond 1.5°C to 2°C can trigger natural and social tipping points which can cascade into a domino effect, many of which are irreversible on time scales of at least few centuries.

6. The food and water security of the world is threatened by climate risks. The world food system is significantly contributing to climate change with about 30% of greenhouse gas emissions. At the same time, the food system is exposed to major risks from climate change, leading to reduced productivity and growing hunger. Climate change interacts with other sources of risks to the resilience of the food systems, in particular loss of biodiversity, and risks such as conflicts, global pandemics such as COVID-19, social inequality and marginalization.
7. Thus far, the poorest three billion people have been at the receiving end of the adverse effects of climate change and loss of the benefits provided by intact natural systems. Global warming has significantly decreased the income of the poorest. The contribution of the poorest three billion to climate pollution is less than 10%, while the wealthiest one billion are responsible for at least 50% or more of the emissions.
8. We emphasize the three combined and interrelated planetary crises: climate change, biodiversity, and inequality. Climate change amplifies also the other two crises, with implications for survival of humans and many species. Climate change has become a multiplier of the underlying socio-economic forces that are responsible for inequality between the wealthiest and the poorest nations, as well as the inequality between the wealthiest and the poorest people within each nation. The inordinate delays in enforcing deep cuts to climate warming emissions has turned the climate crises into a moral problem.
9. The Climate crisis is being compounded by other crises. The COVID-19 pandemic has compounded the problems arising from climate change and inequality. We are now also faced with many wars being waged in the world, such as Russia's invasion of Ukraine, the Tigray war in Ethiopia, Yemen, and others, which have grave negative influences on human survival, inequality, health and wellbeing, migration, food security and climate pollution.
10. Given the intersecting nature of the three crises [Climate, Biodiversity, and Inequality], the design approach of climate solutions must broaden the current focus and include nature-based climate solutions that bring in oceans, mangroves, farm lands and forests, which will contribute to addressing the biodiversity and inequality crises, along with technological and institutional innovations. Nature-based solutions should also be the basis for the built environment transformation. The Amazon is one of the most important biomes on Earth in delivering ecosystem services that are essential to increase resilience of global systems to climate change. But the Amazon is also suffering from a pronounced loss of Resilience. A particular case for just land and natural resource management can be made for Congo basin and the African drylands. Nearly a third of global drylands occur in Africa, where they cover around 19.6 km^2. These two-thirds of Africa's land area are home to the most vulnerable communities, ecosystems, and livelihoods. Energy poverty must be eliminated for climate adaptation plans to succeed. Over 2.5 billion currently rely on firewood, dung, and solid coal for meeting basic energy needs such as cooking and heating, with very little energy and financial resources to cope with heat stress, floods, and droughts. And nearly one billion lack access to electricity. Universal access to affordable clean energy sources must become one of the major milestones for achieving climate resilience.
11. Progress on adaptation is uneven and there are increasing gaps between action taken and what is needed to deal with the increasing risks. Adaptation is intrinsically a national or local issue and therefore requires national or locally-led processes and interventions to improve resilience. Adaptation is cost-effective but vastly under-funded, which reduces implementation. Financial pledges to support developing countries in their efforts to

achieve climate and sustainability ambitions, and the importance of economic indicators have always been at the center of international sustainability debates, but the world has made limited progress on these issues in the last decades.

12. Time is now short to scale up climate mitigation actions and prevent crossing the 2°C or warmer thresholds before 2050. Deep decarbonization by itself, while essential, is not sufficient to limit the warming below 2°C. Additional measures such as deep cuts in emissions of non-CO_2 warming pollutants, extraction of CO_2 that is already up there in the atmosphere, and nature-based solutions must be integrated with deep decarbonization measures.
13. Yet, any approach to resilience building must recognize the fact that it could take three to five decades to bend the global warming curve below 1.5°C. We can no longer take comfort in just relying on climate mitigation. Adaptation to current weather extremes and related climate risk are upon us and should be considered as a central theme in climate policy actions. We need enhanced focus on adaptation challenges, which are confronting the entire world, but particularly the poorer segments of countries and societies.
14. We note that these multiple crises are a challenge for policy actions. Science can and must assist in identifying options for priorities, and actions that are evidence based. In doing so, science-based recommendations must pay close attention to implications for equity. This is a major new rationale for focusing science and policy on resilience.

Recommendations: Three Pillars of the Resilience Pathways

Efforts to build climate resilience must rest on **three pillars**:

Mitigation – Bending the warming curve: Reducing climate hazards through mitigation actions such as deep cuts in emissions is an imperative. First, the wealthy one billion, who are contributing over 50% of the pollution, must reduce their own emissions and provide financial as well as technological assistance for the rest of the world to follow their example.

Adaptation – Addressing inequalities Governance & Access to finance: The second pillar of resilience requires society to start a major effort to help people, especially the poor and the middle class, to adapt to the impacts of climate change now. Special attention must be given for access to energy, water and food for the vulnerable populations, numbering over 3 billion.

Transformation – The Role of Science: The third pillar of resilience is transformation of society, and integrating actions on the climate crisis with actions on the biodiversity crisis. This includes economic systems and policies to be more informed by capturing, tracking and accounting for the values of nature in economic models and sustainable access to natural resources, minimize GHG emissions from all sectors. All this calls for a major engagement of science.

First Pillar: Mitigation – Bending the warming curve below 2C before 2050

1) *Bending the warming curve down: Bend and flatten the warming curve below 2°C before 2050 and bend it further below to 1.5°C before 2100, through deep cuts in emissions of CO_2 and other heat trapping pollutants; and extraction of at least a third of the 1.2 trillion tons of CO_2 from the atmosphere. The wealthy billion must drastically reduce their emissions and provide financial and technological assistance to the poor and vulnerable 4 billion people to enhance their adaptive capacity and to build their resilience.*

1.1) Short-lived climate pollutants (methane, HFCs, surface and lower atmosphere ozone & Black Carbon soot) – With available technologies and current air-pollution governance mechanisms, we can cut the emissions of these pollutants by 40% to 100% within 25 years and cut the rate of warming by about a third to half before 2050.

1.2) Deep Decarbonization – We must bring down the fossil fuel related emissions of CO_2 close to zero before 2050; This is the most important step for keeping the warming below 2°C for the rest of the century and beyond. Carbon mitigation actions that have co-benefits for biodiversity and inequality should be prioritized.

1.3) Atmospheric Carbon Extraction (ACE) – The blanket of carbon dioxide is already too heavy. It now weighs 1.1 trillion tons, and we are emitting about 40 billion tons every year. From now to 2050 we may have to extract as much as 300 billion tons of CO_2 from the air to thin the heat-trapping blanket sufficiently.

2) *Nature-Based Solutions: These include nature-based climate solutions for emission reductions that bring in oceans, mangroves, agroforestry, farmlands, forests and degraded landscapes. These solutions also provide adaptation benefits and offer powerful options for addressing biodiversity and inequality with huge co-benefits for health of people and ecosystem.*

2.1) Nature-based climate solutions, especially those delivered by people-centered approaches, can be more efficient in producing outcomes that are simultaneously relevant for climate, biodiversity and inequality crises. There is an opportunity to scale up people-centered approaches to reduce deforestation, protect biodiversity and reduce inequality in the Amazon, Africa and Asia. New and bold finance mechanism are needed, given the threats or a tipping point on Amazon ecosystem.

2.2) People-centered approaches, embedded with nature-based solution, should use a systemic approach and include goals to improve public health; food and nutrition security; water and energy security, among others. People-based solutions can reduce migration to urban areas which are overcrowded throughout the developing world, with high levels of extreme poverty and violence. Investment in rural resilience can have indirect effects for urban resilience.

2.3) Hybrid interaction of biological processes and technology should become a model for climate-resilient development for the built environment. Buildings adaptation to the ambient conditions resembles biological models, in which such factors as body temperature, humidity, gas and fluid exchange, shape and color modification, allow organisms to adjust to the environment without harmful effects nor resource over-consumption. Natural models enable active metabolism, including air and water quality improvement, pollutant filtration, energy and waste management, and circularity. At the building and city scales, this enables carbon sequestration, natural cooling, humidification, and air purification.

Second Pillar: Adaptation – Addressing Inequalities, Governance & Adapting Systems

Addressing Inequalities

3) *Inequality: Initiate a major effort to help the poor and vulnerable four billion, to adapt to climate risks now. Affordable access to clean energy, water, health care, sustainable farming; and resilient infrastructures must be part of the milestones. It is necessary to consider novel legal instruments to manage climate-forced displacements and survival migration for climate refugees.*

3.1) Social protection and inclusion: Incorporation of the needs and perspectives of the most marginalized users, including indigenous, women, youth, and pastoralists must be a core element of adaptation governance. Social protection and health insurance mechanisms must be expanded. On the social side, behavioral changes for reducing consumption (by the 50% of the population who contribute more than 2/3 of the emissions) and working for the common good are going to be essential attributes for climate risk reductions.

3.2) Eliminating Energy Poverty: The poorest three billion, who now rely on primitive energy technologies, should be given clean energy access that is also affordable. Specifically, eliminating Energy Poverty requires: Governments to develop structured programs when pursuing universal electricity access following the core principles set out in the Integrated Distribution Framework (IDF) adopted by the Global Commission to End Energy Poverty, including a focus on economic impact. In partnership with international experts and institutions, governments should use modern geospatially-referenced tools to plan resilient and affordable energy infrastructure to enable universal access and drive equitable economic growth. To enable this agenda, the international community must be far more generous in supporting access programs with greatly expanded concessional lending and grant-making to poor countries.

3.3) Considering the growing body of evidence on intensifying climate impacts, it is necessary to consider novel legal instruments to manage climate-linked forms of survival migration or to provide legal pathways to move elsewhere in anticipation of uninhabitability. We propose the introduction of a legal document, a Climate Refugee Passport, that would permit citizens of territories that are at high risk of becoming uninhabitable due to climate change impacts to live, work and eventually gain full political rights in other countries, including those that have substantially contributed to global emissions.

Governance

4) *Governance: Solutions should be locally and nationally determined actions. Coordinate the available resources at various levels of government with the local actions.*

4.1) Adaptation solutions should be regionally and locally-led processes and interventions to improve resilience. Implementation of adaptation solutions must have a governance structure that coordinates the available resources at various levels of government with the community level responses. In countries there is limited coordination and connectivity of local organization with central agencies that leads to sub-optimal use of the limited human capital to help network multiple initiatives.

4.2) Taking Africa as a major example for adaptation urgency, an integrated intervention in Africa's drylands should include the following actions and governance structure: Establish new business models for inclusive economies, particularly in growing urban centers to drive sustainable value chains. Create Green Enterprises (social enterprises) who become employers. Establish high-level political commitment to land restoration and tenure security for local benefits. Facilitate strong coordination of local initiatives, e.g., optimize the use of fertile lands such as around small freshwater bodies, wetlands, and riparian ecosystems along rivers that can sustain sustainable intensification production systems.

4.3) New financial mechanisms tied to local ownership and decision-making for indigenous and vulnerable populations. Funding local adaptation action through new mechanisms of direct access to resources by local communities. This allows local communities to build their capacity to develop adaptation programs and implementing adaptation actions.

Adapting Systems

5) *Food & Water Security*: *Worldwide scaling up of the following are required: sustainable land and soil management, forest protection and agroforestry, advanced plant breeding, social protection with nutrition components, water use efficiency in farming, and access to clean drinking water and sanitation. Water security, already threatened perceptibly by global warming and related weather extremes, needs to become a visible element of climate change*

negotiations. A concerted effort is required to reduce food waste and excessive meat consumption.

5.1) The world food system is in an acute crisis that is, to a significant extent, prompted by climate change and related indirect and ripple effects.[3] Numerous practices, technologies, knowledge, and social capital already exist for strengthening food systems resilience, such as sustainable land management, social protection, early warning mechanisms, traditional and local knowledge, agricultural services and extensions, diversification and insurance, and many others. These actions, applied selectively at local scales, need to be scaled up to new areas worldwide. Agro-biodiversity needs more protection as it is a basis for modern plant breeding which is essential for resilient food systems under climate stress. Considerations for food systems resilience should be made an integral and institutionalized part of global efforts to mitigate and adapt to climate change, land degradation neutrality and land restoration under the UN Convention to Combat Desertification, and global and national biodiversity frameworks under the UN Convention on Biological Diversity.

5.2) Agroforestry for resilient and productive landscapes: with its multifunctional properties, agroforestry should be scaled up in rural and urban settings to provide a sound framework for optimizing synergies to reduce climate risks – adaptation and greenhouse gas emissions-mitigation and, at the same time, enhance biodiversity at the interface of agriculture and forestry. Agroforestry solutions should have a mix of the following: an integrated landscape approach with people at the center, co-producing context-specific knowledge, and management options with people at the center, enabling government policies, effective partnerships, direct funding support and long-term commitments. Expanding agroforestry and restoring degraded lands must be complemented with halting deforestation and maintaining forests.

6) *Construction and housing: Transform settlements into carbon banks by prioritizing organic building materials in support of sustainable bio-economy and circularity through multiple material reuse, including such homes which transform today's slum areas.*

6.1) Transforming the built environment is a crucial factor in the climate equation: Buildings and infrastructures are directly responsible for up to 40% of the global greenhouse gas emissions. Novel options for "building better" are becoming available now, such as timber-based high-rise construction, AI-assisted design, serial pre-fabrication of components, smart recycling technology, multi-functional land use, community-based urban development, and so on.

6.2) The resulting bioeconomy must capitalize on both advanced bio-sciences and neglected traditional and indigenous knowledge.

7) *Regional hotspots: Special attention must be given to regional hotpots for climate stress: Amazon, Small Island Nations, Drylands of Africa, Southern and Eastern Africa, Mediterranean, Middle East, South Asia, NE China and South-West USA.*

Third Pillar: Transformation

Transformation: *Change of lifestyle, transformation of society and ecosystems to mitigate, adapt and bounce back. This transformation is akin to an ecological conversion (Pope Francis'*

[3] Science and Innovations for a Sustainable Food System Preparing for the UN Food Systems Summit 2021 https://www.pas.va/en/events/2021/food_systems.html

statement) and must integrate actions on the triplet of crises: climate, biodiversity, and inequality.

8) Transformation of economic systems and societies by moving swiftly to renewable energy systems, applying incentives such as carbon pricing and regulations for reducing demand for emission-intensive goods, including policies that account for the values of nature and take us on a path of stewardship and restoration of Nature. We must also recognize the obligations of wealthy societies providing technological and financial assistance to the less wealthy, and of all societies to pursue scientifically- and environmentally-informed economic development.

8.1) Transformation must be a central feature of resilience and entails the ability to initiate fundamental shifts in behavior and socioeconomic systems including governance, and consumption.

8.2) Integrated solutions and multi-stakeholder cooperation are required, to lead us toward global and local governance to be more responsive to sustainable development.

8.3) The current spending on harmful subsidies for fossil fuels or unsustainable agriculture should be redirected to support universal health coverage, public transport, affordable healthy food choices and other policies that improve health, reduce GHG emissions and promote equity. This reform could also be key for achieving public and political support for climate change action.

8.4) Transformative mitigation aims for energy consumption becoming decoupled from economic growth, by increasing energy efficiency, reducing energy waste, and reducing the carbon intensity of energy consumption.

8.5) The financial sector and governments need to do more on complementing their work with interventions that use indicators and investments in ways that build adaptive capacities. Financial pledges to support developing countries in their efforts to achieve climate and sustainability ambitions should be fulfilled as soon as possible to secure the resilience of vulnerable communities and nature.

8.6) Resilience-building must take center stage of **climate summits** and protect people and ecosystem from unavoidable climate extremes in the coming decades, fostering justice and the crucial good that is peace.

9) Behavioral change of people, communities, and business is needed to achieve the transformation. A major new global initiative is required for mass education of everyone, from children to senior citizens, in ecological citizenship (*Laudato Si'*, para 211) and on sustainable living. Public, civil society and faith-based communities of all world religions can productively engage in this moral task.

Role of Scientific Institutions, Scientists and Educators

10) All of the 9 recommendations above require a major engagement of science. Science must assist in prioritization of evidence-based actions without losing focus on equity issues. The analyses of solutions must include the modeling of two-way natural/social systems interactions to achieve a transformational improvement in the predictive power of climate trajectories.

10.1) **Scientists must act as citizens and consider the question of the earthly future of humanity and of planet Earth** and, as responsible persons, help to prepare for it, preserve it and eliminate the risks, in a resilient way, especially in the current situation of anthropic climate stress, wars, poverty, famine and threats of nuclear catastrophes. The climate policy

agenda and choices raise large ethical issues. Addressing these would benefit from systematic interaction between **science and faith**.[4]

10.2) The science communities focused on mitigation, adaptation and resilience **must move forward together,** as the two can no longer be treated separately, if they ever could. Policy analyses on options addressing mitigation and adaptation need to be tackled in an integrated way, including in climate modelling and scenarios. The design focus and scientific analyses of solutions must consider the two-way coupling between natural systems and social systems. Current models of climate mitigation are too limited in their ability to treat such two-way couplings and feedbacks and, as a result, their predictive capability of future climate trajectories is potentially subject to large and unknown uncertainties.

10.3) **Science based establishment of policy options**: Unprecedented climate change impacts and associated uncertainties in combination with strong economic interests make independent and trustworthy science an essential requisite for achieving climate resilience. It is imperative that every effort to build resilience is rooted in appropriate science and data-driven decision making. The IPCC plays an appropriate role, as do academies of sciences and universities.

10.4) The institutional and organizational set up of science and knowledge generation at national and global levels also require transformational thinking in the areas of interdisciplinary and transdisciplinary science to help guide the transformations needed. Serious considerations must be given for establishing national and regional **Climate Adaptation Science Centers** with partnerships with universities to integrate climate adaptation and resilience science into research and education for preparing future generations of sustainability champions and leaders in resilience science and actions.

III. Background Data

1. Climate/Weather (CW) Statistics

CW-1: 1995-2015: Weather-related disasters claimed 606,000 lives and affected 4.1 billion people with injuries, homelessness and emergencies. Deaths occurred primarily in low-income countries. The number of disasters peaked in China, India and USA; recorded losses totaled $1.9 trillion.

The United Nations Office for Disaster Risk Reduction (UNISDR), 2016. *The Human Cost of Weather-Related Disasters 1995-2015.* https://www.unisdr.org/files/46796_cop21weatherdisastersreport2015.pdf

CW-2: 1970-2019: Weather/climate/water-related disasters led to 2.06 million deaths and economic losses of $3.64 trillion; numbers increased by a factor of five from 1970s to the current decade and the economic costs increased 7-fold from $175.4 billion during 1970-1979 to *$1.3 trillion during current decade.*

World Meteorological Organization (WM) Report, 2021. *WMO Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970-2019)*, WMO-No. 1267. https://library.wmo.int/index.php?lvl=notice_display&id=21930#.Yq9RTC-B2kE

CW-3: 1979 to 2019: Concurrent heatwaves across the Northern Hemisphere mid & high latitudes witnessed about sixfold frequency increase.

Rogers et al., 2022, Sixfold Increase in Historical Northern Hemisphere Concurrent Large Heatwaves Driven by Warming and Changing Atmospheric Circulations. *J Climate*, Feb 2022; American Met. Society. https://doi.org/10.1175/JCLI-D-21-0200.1

CW-4: 1850/1900 to 2020: Hot temperature extremes frequency increased 180% (10-year event) to 380% (50-year event); Heavy precipitation frequency increased 30% (10-year event); Agriculture and ecological droughts in drying regions increased 70%.

Intergovernmental Panel on Climate Change (IPCC-WGI), Report, 2022. *Climate Change 2021: Physical Science Basis.* https://www.ipcc.ch/report/ar6/wg1/

CW-5: 1850/1900 to 2020: The planet warmed by 1.2°C.

[4] *Faith and Science: Towards COP26* https://www.wiltonpark.org.uk/faith-and-science-towards-cop26/ https://www.pas.va/en/news/2021/2021_cop26.html

World Meteorological Organization (WMO): *WMO State of the Climate 2020.* https://library.wmo.int/doc_num.php?explnum_id=10618

CW-6: 1850.1900 to 2021: The planet warmed by 1.1°C. *WMO State of the Climate 2021.* https://public.wmo.int/en/media/press-release/four-key-climate-change-indicators-break-records-2021

2. Inequality (IE) Statistics:

IE-1: Current Period: The poorest 40% of the population, about 3 billion, live on less than $10/day. The middle 45% or about 4 billion, earn between $10/day to $30/day. The combined wealth of the poorest 3 billion is about 2%; and that of the top one billion is 76%. Out of the total global inequality, between countries is 2/3 and 1/3 is within country.

Chancel, L, T Piketty, E Saez, G Zucman (2022). *World Inequality report 2022*. https://wir2022.wid.world

IE-2: Current Period: 50% of the world population are subject to severe water shortages and 3.3 billion people live in countries with high climate vulnerability.

Intergovernmental Panel on Climate Change (IPCC), 2022. *Climate Change 2022: Impacts, Adaptation and Vulnerability. Publishers:* WMO and UNEP: https://www.ipcc.ch/working-group/wg2/

IE-3: Current Period: Of the total GHGs emissions, top 10% produce close to 50% of emissions while the bottom 50% of population (3.8 billion) produce only 12%. The poorest 50% of population in wealthy countries is already at 2030 emission targets. Reference is same as in IE-1.

IE-4: Current Period: An increase of one percentage point in climate vulnerability leads to an increase of 1.5 percent in income inequality. While climate vulnerability has no effect on the distribution of income in advanced economies, the coefficient on climate vulnerability is seven times greater and statistically highly significant in developing countries, which tend to have weaker capacity to adapt to and mitigate the consequences of climate change. Serhan Cevik and João Tovar Jalles, 2022: *For Whom the Bell Tolls: Climate Change and Income Inequality*. International Monetary Fund; WP/22/103.

IE-5: Current Period: Per capita gross domestic product (GDP) has been reduced 17-31% at the poorest four deciles of the country-level per capita GDP distribution, yielding a ratio between the top and bottom deciles that is 25% larger than in a world without global warming. In addition to not sharing equally in the direct benefits of fossil fuel use, many poor countries have been significantly harmed by the warming arising from wealthy countries' energy consumption. Noah S. Diffenbaugh & Marshall Burke, 2019. Global warming has increased global economic inequality. PNAS 116 (20) 9808-9813. https://doi.org/10.1073/pnas.1816020116

3. Resilience (RE) Statistics

RE-1: Current Period: Climate change is the single biggest health threat to people. Global heating of even 1.5°C is not considered safe.

RE-1.1 WHO-2021: COP-26 *Special report on climate change and health*. Published by WHO.

RE-1.2 PAS-PASS-2017: *Health of People, Health of Planet, Our Responsibility*. Proceedings of workshop. Editors: V. Ramanathan, P. Dasgupta and M. Sánchez Sorondo.

RE-2: Health shocks and stresses already currently push around 100 million people into poverty every year, with the impacts of climate change worsening this trend.

RE-2.1 Same reference as in RE-1.1.

RE-3: 2010-Now: 15-fold more people died from floods, droughts and storms in very vulnerable regions, including parts of Africa, South Asia and Central and South America, than in other parts of the world. Climate change is exacerbating mental health issues, including stress and trauma related to extreme weather events and the loss of livelihoods and cultures. Healthy diets are unaffordable to about 3 billion people.

RE-3.1 IAP-2022: *Health in the climate emergency: a global perspective*. Inter Academy Partnership (IAP).

RE-4: 2012: Air pollution from fossil fuels kill 10.5 million people per year.

RE-4.1 K. Vohra, *et al.*, Global mortality from outdoor fine particle pollution generated by fossil fuel combustion, 2021. *Environ. Res.*

RE-5: 1961-2020: Climate change decreased global agriculture productivity by 21%. Air pollution has even larger impacts; in India, air pollution decreased wheat yield by a third.

RE-5.1. Ortiz-Bobea Ariel et al., 2021. Anthropogenic climate change has slowed global agricultural productivity growth. *Nature Climate Change*, 11, 306-312.

RE-5.2. Burney, J., and V. Ramanathan (2014) Recent climate and air pollution impacts on Indian agriculture, *Proc. Natl. Acad. Sci.*

RE-6: Current: Hundreds of millions of the world's poorest people directly depend on smallholder farming systems. These people now face a changing climate and associated societal responses. 84% of the world's more than 570 million farms are small and family-run (less than 2 ha). They operate about 12% of

the world's agricultural land. Smallholders present a greenhouse gas (GHG) mitigation paradox. They emit a small amount of CO_2 per capita and are poor, but they produce GHG intensive food and emit disproportionate quantities of black carbon through traditional biomass energy.

RE-6.1: Sarah K. Lowder et al., 2017: The Number, Size, and Distribution of Farms, Smallholder Farms, and Family Farms Worldwide. *Annu. Rev. Environ. Resour.* 2017. 42:347-75 https://doi.org/10.1146/annurev-environ102016-060946.

RE-6.2: Avery S. Cohn et al., 2017. Smallholder Agriculture and Climate Change. *Annu. Rev. Environ. Resour.* 42:347-75 https://doi.org/10.1146/annurev-environ102016-060946

RE-7: Now until 2100: Future projections by the Agricultural Model Intercomparison and Improvement Project (AgMIP) (RE7.1) suggest that end-of-century maize productivity losses can be as low as -23% under high vulnerability-high warming scenario (RE7.2). Under the same scenario, about one third of the currently suitable area for major crops and livestock production would become unsuitable by the end of the century (RE7.3).

RE-7.1: Rosenzweig, C., F., Tubiello, D., Sandalow, Benoit, P., Hayek, M., 2021. Finding and Fixing Food System Emissions: The Double Helix of Science and Policy. *Environ. Res. Lett.*

RE-7.2; Jägermeyr, J., et al., 2021. Climate impacts on global agriculture emerge earlier in new generation of climate and crop models. *Nat. Food* 2, 873-885. https://doi.org/10.1038/s43016-021-00400-y

RE-7.3: 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, 720-729. https://doi.org/https://doi.org/10.1016/j.oneear.2021.04.017

RE-8: Current: Globally, agriculture accounts for 72 percent of all surface and groundwater withdrawals, mainly for irrigation. Rainfed farming produces 60 percent of the world's food on 80 percent of the cultivated land. Irrigated farming produces 40 percent on 20 percent of the land. Agriculture is a significant contributor to water stress in countries with high levels of water stress. Rainfed and irrigated agriculture are operating at the limit of sustainability. 98 percent of global calorie production is derived from land and there is little room for expansion. Complex feedback loops between climate and land present agriculture with amplified levels of risk. Of the 2.2 billion ha of degraded land identified as potentially (biophysically) available for restoration worldwide, 1.5 billion ha may be best suited for mosaic restoration combining forests and trees with agriculture. A further 1 billion ha of croplands on previous forestlands affected by land-use change would benefit from strategic additions of trees to increase agricultural productivity and the provision of ecosystem services. Agroforestry systems tend to be more resilient than conventional agriculture to environmental shocks and the effects of climate change. Depending on the system and local conditions, agroforestry can achieve 50-80 percent of the biodiversity of natural forests; increase food security and nutrition by serving as a safety net; and increase crop productivity.

RE-8.1: FAO-2022. The State of the World's Land and Water Resources for Food and Agriculture: Systems at Breaking Point, *FAO Synthesis Report 2021*. https://www.fao.org/land-water/solaw2021/en/

RE-9: Water security is threatened by the intensification of the hydrological cycle caused by global warming and related weather extremes. Currently, roughly half of worlds ~8 billion people are estimated to experience severe water scarcity for at least some part of the year due to climatic and non-climatic factors (medium confidence[1]). Since the 1970s, 44% of all disaster events have been flood-related. Not surprisingly, a large share of adaptation interventions (~60%) are forged in response to water-related hazards. In 2017, approximately 2.2 billion people lacked access to safe drinking water, and roughly 4.2 billion people could not access safe sanitation. At a global warming of about 2°C, between 0.9 and 3.9 billion people are projected to be at increased exposure to water stress, depending on regional patterns of climate change and the socioeconomic scenarios considered.

RE-9.1: Caretta, M.J, A. Mukherji et al., 2022: Water. Chapter 4 of *Climate Change 2022: Impacts, Adaptation and Vulnerability.* Working Group II, Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 551-712, doi:10.1017/9781009325844.006.

RE-10: 2000 to Now: Pronounced loss of Amazon Forest Resilience since the early 2000s, may be approaching tipping point.

RE-10.1: Boulton, C.A, Lenton, T. M, Niklas Boers; 2022: Pronounced loss of Amazon rainforest resilience since the early 2000s. *Nature Climate Change*, 12.

RE-11: Current and Future: Mass coral bleaching is underway. 99% of coral reefs are projected to be lost when warming exceeds 2°C.

RE-11.1: IPCC, 2018: Summary for Policymakers. In: *Global warming of 1.5°C.* https://www.ipcc.ch/sr15/chapter/spm/.

RE-12: Current: Amundsen Sea embayment of West Antarctica might have passed a tipping point; When this sector collapses, it could destabilize the West Antarctic ice sheet. Part of the East Antarctic ice sheet – the Wilkes Basin – and the Greenland ice sheet which is melting at an accelerated rate might be similarly unstable. Sea ice is shrinking rapidly in the Arctic and at 2°C warming, the region has a 10-35% chance of becoming largely ice-free in summer.

RE12.1: IPCC-2019. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate.* https://www.ipcc.ch/srocc/; RE12.2: Lenton, T., et al., 2019. Climate tipping points – too risky to bet against. *Nature*, 575.

4. Biodiversity (BD) Statistics

BD-1: Current: Biodiversity is the rich variety of living things that, woven together, support and sustain life on Earth. The continued health of all life on the planet, including human life, depends on making choices that will protect biodiversity.

BD-1.1: National Academy of Sciences Report, 2022. *Biodiversity at Risk.* NAS Press. https://www.nationalacademies.org/news/2022/01/biodiversity-at-risk-new-booklet

BD-2: Current: The loss of species is 10 to 100 times faster than in pre-human times. At least 1 million species are currently threatened with extinction.

BD-2.1: Same as BD-1.1

BD-3: Coming Decades: Climate change is projected to be the biggest single threat to biodiversity in the coming years.

BD-3: Same as BD-1.1

BD-4: Current: Nature and its vital contributions to people, which together embody biodiversity and ecosystem functions and services, are deteriorating worldwide. Biodiversity – the diversity within species, between species and of ecosystems – is declining faster than at any time in human history.

BD-4.1: IPBES, 2019: *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* E.S. Brondizio, J. Settele, S. Díaz, and H.T. Ngo (editors). IPBES Secretariat, Bonn, Germany. 1148 pages. https://doi.org/10.5281/zenodo.3831673

BD-5: Current: More than 75% of global food crop types, including fruits and vegetables and some of the most important cash crops, such as coffee, cocoa and almonds, rely on animal pollination.

BD-5.1: Same as BD-4.1.

BD-6: Current: 75% of the land surface is significantly altered, 66% of the ocean area is experiencing increasing cumulative impacts and over 85% of wetlands area has been lost. Across much of the highly biodiverse tropics, 32 million hectares of primary or recovering forest were lost between 2010 and 2015.

BD-6.1: Same as BD-4.1.

BD-7: The direct drivers of change in nature with the largest global impact have been (starting with those with most impact): changes in land and sea use; direct exploitation of organisms; climate change; pollution; and invasion of alien species. Climate change is a direct driver that is increasingly exacerbating the impact of other drivers on nature and human well-being. Increase in extreme weather and sea level rise have contributed to widespread impacts in many aspects of biodiversity, including species distribution, phenology, population dynamics, community structure and ecosystem function.

BD-7.1: Same as BD-4.1.

BD-8: Limiting global warming to ensure a habitable climate and protecting biodiversity are mutually supporting goals, and their achievement is essential for sustainably and equitably providing benefits to people. The adaptive capacity of most ecosystems and social-ecological systems will be exceeded by unabated anthropogenic climate change, and significant adaptive capacity will be required to cope with residual climate change even under ambitious emissions reduction. Tropical coral reefs, savannas, tropical forests, high latitude and altitude ecosystems and Mediterranean-climate ecosystems, and coastal ecosystems are already highly impacted, and require robust intervention.

BD-8.1: *IPBES-IPCC Workshop Report*, 2021. IPBES-IPCC Co-Sponsored Workshop Report on Biodiversity and Climate Change. https://ipbes.net/events/ipbes-ipcc-co-sponsored-workshop-report-biodiversity-and-climate-change.