Francesco Ferrini — Planning and Managing Green Cities for Human Health and Well-being

Henry Miller: [00:00:12] Hello and welcome to the ISA Conference Rewind video series. I'm Henry Miller at the International Society of Arboriculture. Today, ISA is proud to bring you a presentation by Francesco Ferrini on planning and managing green cities for human health and well-being. This presentation was originally given at the 2023 ISA Virtual Conference, so the views seen here are those of the presenters. So, if you would like to learn about research trends related to green infrastructure and urban greening, as well as targets your city can reach to improve human health, I expect you will like this presentation. Now, sit back and enjoy.

Francesco Ferrini: Hello, my name is Francesco Ferrini. I work at the University of Florence in Italy, and today I will speak about [00:01:00] planning and managing green cities for human health and well-being. You know that the city and the world are changing rapidly. The latest trends are the reason more and higher appreciation of nature—the so-called Green Revolution, green infrastructure as mitigation and adaptation strategy to climate change—are becoming more and more familiar. We know that nature base solutions are good, but they are not enough. So, urban nature becomes mainstream based on the concept of nature-based thinking instead of nature-based solution. You can see this by the number of papers you can find in the database Scopus by using the keywords health and urban green and urban green spaces. I tried to do this a couple months ago and then a few weeks ago. [00:02:00] You can see that there is a sharp increase in papers published in the international literature about human health and well-being and urban green spaces. Just in a month, more than 50 papers, almost 50 papers actually have been published on this on these topics.

So, we have to think, who are cities for? Because so far, we have planned and realized cities were for the cars and were for the buildings and not for the people, but in the next future, we have to think about cities that will be made for the people to live in. So, we had to set some targets for the city of the future. We have to think about cities for people. Which are the main targets for these? The first target is the one I will speak on today. It is to improve health and well-being. [00:03:00] The targets are mitigating the urban heat island, stormwater management, reducing pollution, preserving biodiversity, and then increasing CO2 storage. Actually, all these targets are together important to improve health and well-being. So, I will speak about that, but also, try to say something about all the others. All the other targets. So, the targets are important, but also it's important that targets are specific, measurable, achievable, relevant, and time-based to have a really SMART city.

The first target is planning to mitigate urban heat island. For me and for people who live in the southern part of Europe and also in the southern part of the United States and other countries, urban heat island [00:04:00] is becoming probably the most important problem to face now and to face in the next future. I don't know if you remember, but probably the people who are old like I am will remember the song by Joni Mitchell. This was written, composed, and originally recorded by this Canadian singer. The song is known for its environmental concern. If you remember the refrain is "they paved paradise to put up a parking lot." Then she said, "hey farmer, farmer put away

that DDT now," and it's a very sentimental sound. She also refers to the trees that will be placed in a museum and charge the people a dollar and a half just to see them. [00:05:00] She refers to the Foster Botanical Gardens in downtown Honolulu, which is a living museum of tropical plants, some rare and endangered.

You can see from this slide that there is a strict relationship between soil sealing and rise in temperature. This is research made by some colleagues of mine at the University of Florence and National Research Council that shows how with an increase of 20% of soil sealing, there is an increase of 0.6 °C in surface temperature in Rome. This is a very important change in land surface temperature all along the soil. The more paved, the more impermeabilized a surface, the higher is the land surface temperature, which is quite obvious. [00:06:00] You see also the relationships that there is from the proportion of green infrastructure and the average additional heat. You know, the higher is the percentage of green infrastructure, the lower is the average additional heat. The difference is about 5 to 6 °centigrade, which is a very high difference.

So, trees can be a solution, but you have to know how many trees, where to place these trees, and which species should be used to improve or to decrease the urban heat island. You see some from this slide, originally published by some authors in 2021, they compared the regional landscape with some trees with the landscape with more trees, and the difference in the temperature is 2 degrees less. [00:07:00] By planting 20 more trees but placing them in a very strategical way, you can decrease the temperature 1 °C more or 1.5 °F. So, just planting trees can be a solution. It's a part of the solution, because it's not so simple. Those who are involved in planting tree projects all over the world know very well how difficult it is sometimes to get real good results. So, planting trees is a very complex thing. We need to know what plant, what to plant, when to plant, how to plant, why plant—because there must be a reason why we should plant trees there or there—way to plant them, and who should be in charge of planting trees in our cities. [00:08:00] Also, it's not important just the tree cover but also for example, biodiversity has been correlated in a positive way with the extent of cooling. So, the more biodiverse our urban forest, the higher the effect on air temperature. So, to have different species, different canopy shape, different tree, different leaf form, it's important to have a bigger effect on air temperature.

From this slide, you can see that it's a summary of the different findings of the effect of green space on cooling temperature in the city. You see that different shapes also of green areas are important to increase the effect on urban heat island, the same for the tree canopy. [00:09:00] Different tree canopy shapes can have different results in terms of cooling. Also, leaf trait identities is important. Also, the tree size and the canopy density is important. It's why you know obviously the bigger the trees and the higher is the effect on the reduction in roadside temperature. At the same time, you can see that the canopy density is also important. So, it's important to have big trees with the quite dense canopy to have a bigger effect on temperature reduction.

This is very interesting. It is a photo taken with infrared camera. [00:10:00] You can see how different vegetation can have different effects on cooling the air. Just planting trees can reduce in this research can reduce 0.6 °C temperature. Planting trees and shrubs can have a higher effect, 0.9. But trying to make a secondary forest has a much bigger effect, 1.7 °C. It means that the

difference between planting just trees or planting secondary forests with trees, shrubs, and the understory vegetation has an effect which has three times as much of that obtained by just planting trees.

[00:11:00] We have done and we're doing some research in my city, which is Florence in Italy. Florence is climate change, it is becoming hotter, hotter, and hotter. This is a picture of the city. This part in blue is the biggest urban park in Florence. This is the downtown Florence, and this area is there with the fruit markets. A fruit market and other activities are carried out. So, with some colleagues from the National Research Council, we tried to map the term of hotspots and the urban microclimate in the city and to [00:12:00] run some models to have some regeneration scenarios. You see this is the area I mentioned, the fruit market and other industrial activity, which is the Northwest part of the city. This is the basic scenario, then improved scenario, and green scenario. The results, as you see in this picture that I had taken from these two papers published by these colleagues here in Florence, you can see that the surface thermal hot-spot areas, and especially industrial and commercial areas mainly characterized by high act official surface and low vegetation coverage, consistently affect the livability in urban areas.

In these two studies, one of the warmest areas of Florence, as I say, [00:13:00] the mainly fruit market was selected to perform tree design mitigation scenarios, mitigation intervention by using 5-meter-high trees, and then intervention with 10-meter-high trees, and then intervention alternating 5- and 10-meter-high trees. Just to go to the conclusion, we found—they found actually—very useful information for urban planners and landscape architects to plan targeted intervention aimed at mitigating the urban thermal anomalies in these industrial areas, because you know, just by adding some trees, the temperature, as you can see in the surface temperature ex-post scenario, was lowered in dealing in several parts of these of these areas.

[00:14:00] This is the research we have done. We had finished actually two years ago. It's Life Project funded by European Union. The name is Urban Green. You can find all the information through the internet. We measured the transpiration in microclimate improvement in Rimini, which is a small city in central Italy, and in Krakow, which is a much bigger city in Poland. We found some effects of species and season, but you can see that horse chestnut is much less effective compared to black poplar. Black poplar is a typical Italian native species. The black poplar can dissipate 488 kilojoules in one hour on average, the yearly average while the horse chestnut can dissipate less. [00:15:00] They have 215 kilojoules. So, there is a big difference between these two species. The message is that if you want to reduce urban heat island effect it's much better to use black poplar instead of using horse chestnut. Or for example, you can also use English oak or holm oak and also *Tilia* to have much better effect on things.

In other research we have done, it has been presented to several conferences over the world, even at the ISA conference a couple of years ago, was funded by the Tree Fund. We compared for 10 years trees which we have planted in three different soil treatments with control. Sorry, four soil treatments. [00:16:00] The first one was impermeable design which was asphalt on a concrete sub-grade. Permeable design: curb on a crushed rock sub-grade. The porous design, we use an epoxy resin plus even-graded inert on a crushed rock sub-grade. So, the same sub-grade to have the same initial condition, then we also used some control plus we unpaved areas. This picture was made by using a thermal camera, which highlighted the warmest surface temperature in

impermeable, you see, and permeable plots compared to control and to porous ones. So, it's a very important effect of the soil covering material on the production of urban heat island. [00:17:00] The two plots—permeable and impermeable—are much colder compared to control and just—sorry—are much warmer when compared to porous and controlled plots.

You know, we have harvested 10 years of data, but probably this picture and this one can show exactly what happened. The porous material was much colder compared to the asphalt, which is this one and paved materials. So just these two picture, this one using snow, you see that asphalt is much warmer compared to the bare ground and compared to the porous material used as a soil covering material. [00:18:00] So, these results were published as I told you in this journal last year in October 2022, so you can you can find all the results of the research just using this title.

Another important thing is that urban green spaces are also a matter of environmental justice. This is recent research which has compared the land surface temperature and the median household income. You can see how their household income is inversely correlated with land surface temperature. The higher the household income, the lower the land surface temperature. [00:19:00] So, it means that people who are you know, on the poor side of the of the society are also those who are experiencing the higher effect of urban heat island.

Another important target to meet is to reduce pollution. On average one square centimeter of leaf area absorbs between 10 and 70 mg of particulate matter per year. Generally speaking, broadleaved trees are generally more affected than conifer, and evergreens are more affected than deciduous species, which is quite intuitive. Air pollution is a big problem in some parts of Europe. You see this map of Europe, and you can easily find, easily see how Poland, [00:20:00] the Balkan countries, and the north part of Italy are the most polluted areas in Europe with the values which are much higher than the level which were considered as safe air recommendation by the World Health Organization in 2021. You see that according to these papers, 98% of Europeans breathe in highly damaging, polluted air are linked to 400,000—that's a year. It means people who die before 70 because of problems related to pollution. [00:21:00] You know, 400,000 people had a huge amount, a huge toll we have to pay for this. So, we have to work as strong as we can to reduce the air pollution in Europe and especially in Italy, which is my country. You see that these are the premature deaths (years of life lost) attributable to exposure to PM2.5 above the 2021 WHO guidelines. You see that, as I said before the Balkan countries and Italy and Poland and also some East European countries are the most affected by these problems.

Just by meeting the World Health Organization recommendation, we can reduce 43,000 deaths each year because of the high pollution in some parts of Europe. [00:22:00] It's a huge amount of people who can be saved. Also, it is not just a matter of life-death toll, but also, you see from this slide, how many hours of risk per person per year, which are increasing from 1990, especially in the southern part of Europe—Spain, Italy, Greece, and south of France, and so on and also some other part of Europe.

You see that the amount of hours increased from 350 in 1992 to 600 in 2022. Still a huge increment we have to work to reduce as much as we can. So, we need more trees in our city soon. [00:23:00] This is the effect of vegetated and non-vegetative cover on land surface

temperature on a daily basis calculated by fitting generalized linear mixed models on a subset of if, I will remember, 120,000 land use units, and by using suburbs as a random effect to account for local effects on land surface temperature due to distance from the course as well as autocorrelation of vegetation distribution within suburbs. More affluent suburbs are often leafier than less affluent ones. As I said before, you can see easily the higher is the canopy cover and the lower is the land surface temperature. [00:24:00] As I said before just to remark these important concepts.

Also, it's important to use the right species. Planting trees as I said before is very important, but it's also important to plant the right species for the for the target we have to meet. For example, these are two typical European species, which are also grown in the United States. Mountain maple on the left, Norway maple on the right. They are very similar. Very close to the other, genetically close, but they are very different in terms of leaf shape and leaf morphology. mountain maple has very rough leaves and [00:25:00] very heavy leaves compared to the Norway maple. Its effect, for example, particulate matter is four times, three to four times better than Norway maple. So, if you want to reduce PMX from the air, it's much better to use mountain maple or a similar species with very rough leaves and very heavy leaves, instead of using tree species, which have very smooth leaves without any air.

This is the research we did a few years ago. We have published in *Urban Forest and Urban Greening*. We compared different shrubs. Shrubs are very important, because they can intersect pollutants at the height of our mouth and nose. [00:26:00] So, at the height where we breathe the air, you see that for example, *Elaeagnus* x *ebbingei*, is much better than other species or evergreen shrubs in intersecting heavy metal like lead, zinc, or nickel. Why? *Laurus nobilis*, which is our native species in Italy, is much better for intercepting copper. In other research, we have done, you see my name on the authors of this research, we compared the air pollution deposition by a roadside vegetation barrier made of different species with different density different distance from the road at different height, and what we have found out of this research [00:27:00] is that as you can see in the summary of this of this research that the higher leaf area index induce a higher deposition while planting density was not so important. The vegetation barrier also changed the deposition dynamics in the experimental site, so we can say that it's important also to know the characteristics of the barrier. Then we have found that there is a different element composition in the different species, but these are the details probably we publish in another in another paper.

In other research we have done, it's the Life Urban Green which I showed before. We also measure some ecosystem services like particulate [00:28:00] pollution captured by 17 woody species. We found that for example holm oak and Italian stone pine are much more effective than other species in intercepting the three different categories of particulate matter: the ultrafine, the fine, and the PM10-100. It's important also to see that the bottom of the canopy usually is most effective to capture particulate matter. So, it's important also to have vegetation close to the pollution source. These other two papers we have published in the past, still regarding the role of vegetation as a [00:29:00] mitigating factor for reducing pollution and improving thermal comfort. It's also important to know that sometimes, like in this case, the canopy density has a very strong effect in reducing particulate matter. This research is very interesting because it concluded that a sparse canopy density is optimal for trees in areas with high particulate matter

concentrations. So, the average density of the canopy also favors the dispersion of pollutants, especially PM2.5, while the density of the dense canopy often causes deterioration, so the worsening of air quality.

So, it's important also to know [00:30:00] that the density of the canopy, if the canopy is too dense sometimes, it is just opposite results compared to the sparse density. Also, it's important that there is a correlation between the air pollution and the air temperature. You see this research is very important. It says that the risk of all-cause mortality increased by 6.1% on days with extreme maximum temperature, and by 5% on extreme days with high PM2.5 concentration compared to non-extreme days. But the risk increased by 21% on days with exposure to both extreme maximum temperature and PM2.5. [00:31:00] So the increase in this case of cardiovascular and respiratory mortality on days of extreme exposure was 29.9% and 38% respectively and was greater than the sum of the individual effects of extreme temperature and PM2.5. These estimates were even bigger for the people with the age over 75. These are the two papers connected to this.

So, it's important to plan as I said at the very beginning to plan the green areas of the city of the future to improve health and well-being. We have to consider all the factors I have talked about so far. We know that health is not a simple word. [00:32:00] Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity. And what nature can do for us? It is very simple. This side, I think talks by itself. You see that with increasing green space in the neighborhood, the lower is the death rate. This is probably the most important thing. You can reduce the death rate just by increasing the green in your area. This is the relationship between the amount of green space in a 3 km radius, about 2 miles, and self-perceived health.

So, people are doing much better, feeling so much better than when they live in a green area neighborhood compared to the people who live in less green, within neighborhood with less green area surface. [00:33:00] These are research which was done in Albania in the western part of Europe. You see how there is an inverse relationship between diabetes mortality, cardiac mortality, and Pulmonary mortality, and the amount of green spaces. So, the higher the amount of green spaces, the lower the mortality for this tree factor. So, this spectrum of forms of nature contact. See that there are many forms of nature contact varying by spatial scale, proximity, the sensory pathway through which nature is experienced (visual, auditory, and by touching, and so on). So, this slide shows what is an example of nature contact along just [00:34:00] two scales: spatial and temporal. I think the researchers must define the specific form of nature content they are starting, because sometimes, you know, it's a bit confusing.

I think all these things I have said so far bring us to the concept of forest therapy. Some years ago, we published this paper which was done with some psychologist from University of Rome. The title was “Go greener, feel better?” We found that there was a positive effect of biodiversity on the well-being of individuals. So also biodiversity, we will see at the end of this presentation is very important for improved health and well-being. And so, the effect of forest bathing is very important. [00:35:00] It also has effects on human immune function as shown by this research published a few years ago. You see how the adrenaline concentration was reduced after a forest

trip, why it was a bit increased by a city trip. So having a walk in the woods is very important also to reduce the adrenaline concentration in our body.

Then we have to plan for stormwater management. We have a big problem, you know, flooding in several cities some weeks ago. I have seen some videos and pictures of New York, which was flooded. Unfortunately, my country was severely hit by some local flood which also caused some death [00:36:00] and we have to think about urban green areas like a green filter instead of having cities which are a gray funnel. We have planned cities in the past to allow pollution and toxins to be washed as fast as possible into our waterways. Also with this, we lost and we are losing a lot of water that can be stored and then reused for irrigation during the driest month. So, we have to improve the filtering effect of soil and vegetation. In this way, rainwater can slowly sink into the ground.

You know in the planning and design process of the future city, [00:37:00] we have to think about reducing the impact by reducing soil seedling and soil covering because these will negatively affect the urban heat island. It will negatively affect also the pollution the pollutant concentration, and also will have negative impacts on stormwater management as you can see in this slide from this publication. So, it's also important to species. You know, rainfall interception depends on tree management, bark characteristics, leaf insertion angle, leaf type, and canopy shape. For example, runoff can be reduced with larger trees compared to small trees and with canopy with the [00:38:00] denser canopy compared to a less dense canopy. Also, you can see that evergreen street trees can have a higher effect compared to deciduous street trees. Also, the same species you see in this slide how different is the stormwater interception according to the different age and obviously sides of a tree. A five-year old hackberry can intercept 0.5 cubic meter of rainfall per year while a forty-year-old hackberry can intercept 20.4 cubic meters of rainfall each year. So, several times, 40 times as much compared to a young, very young tree.

All green areas are important, from the grass strip, [00:39:00] the playground, the grass, the street trees, the private and public gardens. The most important thing is that we have to think about our green areas like cogs in an engine that drives a city in a sustainable way. So, we shouldn't plan the green areas like, you know single ones, but in the whole city system to have the better results. Also, at the end, we have to plan for increasing CO2 storage. For example, CO2 is mostly stored in large parks, and it's obvious but it's very important also to know that lawn areas are not so effective. [00:40:00] So, we should reduce the lawn areas to favor the planting of large and deciduous trees and also introducing evergreens suitable for the urban environment. To know the difference between carbon assimilation, carbon sequestration, and carbon storage. Still the same project was a huge project with some colleagues from University of Milan, University of Krakow, and local municipalities. You see how for example also in this case black poplar and English oak were much more effective in CO2 assimilation, sequestration, and storage compared to box elder or horse chestnut. Still the same papers I showed you before. This was in Rimini. This was in Krakcow. You see also in Krakow black poplar, English oak were much more effective compared to horse chesnut, and in this case, compared to rowan.

[00:41:00] Last but not the least, planning to preserve and to increase biodiversity. Biodiversity, as I showed before, is very important. It's fundamental for the future city and the world. We should think about this phrase which was said by the third president of the United States,

Thomas Jefferson, who was also an environmentalist. He said that "if one link in nature's chain might be lost, another and another might be lost, till this whole system of things should evanish by piece-meal." So, it's very important to preserve any kind of biodiversity, and it's important 24/7 to increase biodiversity in our cities. You see how the extinctions of species is strictly correlated with the increase in human population. [00:42:00] We have to reverse this process, which is very dangerous for our world. You see here the cost of inaction on biodiversity loss, which is very high.

It's estimated that from 1997 to 2011, land cover changes caused losses of between 3.5 thousand 3.5 thousand and 18.5 thousand billion dollars per year in ecosystem services globally, and that land degradation cost about 5.5 thousand to ten to five thousand billion per year on a world basis. More precisely, you can see in this slide, [00:43:00] biodiversity loss reduces agricultural yields and fish catches, increases economic losses due to floods and other disasters, and deprives us of potential new sources of medicine. Even we will make the biggest effort to reduce the loss of biodiversity will have the same biodiversity we had in 2010, in 2050, 2060 if we continue to behave business as usual. You see how the loss of biodiversity will increase to lose 17% of the total biodiversity in the 2100s.

Unfortunately, we are now living in the period of war. You see how war and military activities had a very negative effect on biodiversity and on the environment. [00:44:00] We can say that the biodiversity is the side victim of war, and we don't know how much biodiversity we will lose when these wars in the world will be finished. We are doing something at the national level. There is a huge research plan in Italy with the fund provided by the Recovery Plan of the European Union. Last year was funded by the National Biodiversity Future Center with different AREA resources, integrated designs, evaluation of the effect, monitoring, restoration, and sustainable management. There is a Spoke 5, which is urban biodiversity coordinated by University of Milan and coordinating the unit in Florence. You see we are comparing different species, mainly native species, [00:45:00] according to their drought tolerance, pollution tolerance, and so on. Then we'll plan these species in different areas in central, north, and south of Italy, trying to resembling like, you know a natural scheme.

So, we have this planting scheme, different treatments, modular planting density, and so on. So, it's a huge project that will be finished in 2026. Then we have another project: 10,000 trees for Padua, which is northeast part of Italy. We started last year by planting all these trees in different parts of the city. To me, the most important thing is to have the highest biodiversity possible. [00:46:00] So, several species were planted in different parts of the city, and now we are checking the ecophysiological performance and the ecosystem services provided by these trees. We have also have a different experiment: the effect of nursery production methods on growth and physiology, effects of pruning at transplanting, and then a quantification of some ecosystem services on environmental regulation of some tree species.

So, the end is: let's plant more trees. As I said before, it is not an easy task. Also because we have to think about the regeneration of some cities. And regeneration does not mean to redevelop or truly big or to repair. Because the goal, as I have written in this slide, the goal of the urban regeneration is to help make cities sustainable and more on a human scale, [00:47:00] limiting soil consumption or to depave these areas. So, we need to reshape the cities. It is changing from

gray to green. The first thing is to avoid impacts. We should preserve natural features by using conservative planting techniques. According to the DNSH, which is an acronym that means Do No Significant Harm. So, any action, anything, any plan, any program that will be done in the next future in Europe must respect this principle. It must not have any harmful effects on the environment. Second, we have to reduce the impact. We know that any time we do something, [00:48:00] we have some impacts. We have to reduce the impacts, for example, by reducing soil sealing and impermeabilization. Then we have to manage the impacts by using any techniques like the low impact development, the sustainable urban drainage system, or the water-sensitive urban design for the storm water management.

So, nature base solutions, as I said in the very beginning of this talk, are very important, but they do not work alone. They have to work together with social justice with urban green strategies to adopted co-management with the governance of the city and so on. It probably should change to nature-based thinking. So, our challenge is to strategically expand the urban forest and [00:49:00] to provide our community, particularly the vulnerable with healthier, happier, and enriched lives. For these, we need knowledge from different subjects. So, not just knowledge about trees, about tree physiology, tree management, and so on, but we have to cooperate with other people who work on well-being, who have knowledge about economy, landscape, hydrology, psychology, sociology, and so on.

We should have in mind this governance platform to adopt financial strategy and mechanics to support people's health and all these, you know, different things that I have put in this slide to improve the health and well-being [00:50:00] of the people in our city. We should remember that in 2050, 2/3 of the entire population in the world will live in urban—probably more than 2/3—will live in urban areas, so we had to plan and to analyze cities which will be able to host all these people and to improve the life of these people. I finish with this picture. I'm the editor of the, together with a colleague in the University of Milan, of this new journal, Frontiers in Horticulture. I'm also working for the college of urban forests. So, I encourage the researchers to submit papers to this journal to have their papers published and to let us know about their research. [00:51:00] So, I'm not sure if I have to thank you for your attention or if I have to thank you for not sleeping during my presentation, but anyway, thanks for listening to this long, long top.